UPLAND AND RIVER OPERABLE UNITS REMEDIAL INVESTIGATION REPORT

Bradford Island
Cascade Locks, Oregon

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Prepared for:

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ACRONYMS

%	percent
AOPC	area of potential concern
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tank
ATL	Acceptable Tissue Level
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
B2EHP	bis(2-ethyl hexyl)phthalate
BAF	bioaccumulation factor
BHHRA	baseline human health risk assessment
BCF	bioconcentration factor
BERA	baseline ecological risk assessment
bgs	below ground surface
BSAF	biota-sediment accumulation factor
C	concentration
CB-1	catch basin #1
CB-2	catch basin #2
CEC	contaminant of ecological concern
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CEM	conceptual exposure model
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIC	community involvement committee
C_{ij}	concentration of contaminant *i* in medium *j*
COC	chemicals of concern
COI	contaminant of interest
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPEC	contaminant of potential ecological concern
CRITFC	Columbia River Inter-Tribal Fish Commission
CSM	conceptual site model
CTL	Critical Tissue Level
cy	cubic yards
DART	Data Access in Real Time
DEQ	(Oregon) Department of Environmental Quality
DCA	dichloroethane
DCE	dichloroethene
DHS	(Oregon) Department of Human Services
DNOP	di-n-octyl phthalate
DoD	Department of Defense
DQO	data quality objective
DRO	diesel range organics
DSR	data sufficiency report
DTSC	Department of Toxic Substances Control
Ecology	Washington State Department of Ecology

EcoSSLs	Ecological Soil Screening Levels
ECSI	Environmental Cleanup Site Information
EDQW	Environmental Data Quality Workgroup
EE/CA	engineering evaluation/cost analysis
ELCR	excess lifetime cancer risk
EMPC	estimated maximum potential concentration
EPC	exposure point concentration
ERA	ecological risk assessment
ESA	Endangered Species Act
ESU	evolutionarily significant unit
ºF	degree(s) Fahrenheit
FS	feasibility study
GRO	gasoline range organics
HAI	Huang and Associates, Inc
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HMSA	hazardous material storage area
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
HTRW	hazardous, toxic, and radiological waste
IRIS	Integrated Risk Information System
ITR	independent technical review
kg	kilogram(s)
km	kilometer
K-M	Kaplan–Meier
L	liter(s)
LCFRB	Lower Columbia Fish Recovery Board
log K_{ow}	octanol-water partition coefficient
LOQ	Limit of Quantitation
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LWG	Lower Willamette Group
µg	microgram(s)
µm	micrometer
MCL	Maximum Contaminant Levels
MDD	minimum detectable differences
MDL	method detection limit
mg	milligram(s)
mm	millimeter
MP	Management Plan
MRL	method reporting limit
msl	mean sea level
NCP	National Contingency Plan
ND	not detected
NFA	No Further Action
NHPA	National Historic Preservation Act

N_{ij}	total number of *i* contaminants in medium *j* for which an SLV is available
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NPL	National Priorities List
NRWQC	National Recommended Water Quality Criteria
OAR	Oregon Administrative Rules
ODFW	Oregon Department of Fish and Wildlife
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PA	preliminary assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PDT	project delivery team
pg	picogram(s)
PM	project manager
PRG	Preliminary Remediation Goal
Q	receptor designator
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
R_{BAC}	bioaccumulation index for chemical
RBC	Risk-Based Concentrations
RCRA	Resource Conservation and Recovery Act
RDL	reported detection limit
RI	remedial investigation
RI/FS	remedial investigation/ feasibility study
RM	river mile
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RRO	residual range organics
RSL	Regional Screening Levels
RTC	Response to Comments
SI	site inspection
SLV	screening level value
SLV_{ij}	screening level value for contaminant *i* in medium *j*
SPLP	Synthetic Precipitation Leaching Procedure
SPMD	Semi permeable membrane device
SSI	supplemental site inspection
SVOC	semivolatile organic compound
SWDIV	Southwest Division
TAG	technical advisory group
TBD	to be determined
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure

TDS	total dissolved solids
TEQ	toxicity equivalence quotient
T_{ij}	toxicity ratio for contaminant *i* in medium *j*
T_j	summation of toxicity ratios for *i* contaminants in medium *j*
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
TRW	Technical Review Workgroup
UCL	upper confidence limit
UPL	upper prediction limit
URS	URS Corporation
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WDF	Washington Department of Fisheries
WDOH	Washington Department of Health
WQC	Water Quality Criteria

Bradford Island is part of the Bonneville Dam complex, located on the Columbia River at river mile (RM) 146.1, approximately 40 miles east of Portland, Oregon. The site is a multipurpose facility that consists of the First and Second Powerhouses, the old and new navigation locks, and a spillway. Numerous investigations have been performed by the United States Army Corps of Engineers (USACE) and their contractors since 1997, focusing on two operable units (OUs), the Upland OU and the River OU. The Upland OU includes four areas of potential concern (AOPCs): the Landfill AOPC, Sandblast Area AOPC, Pistol Range AOPC, and Bulb Slope AOPC.

This Remedial Investigation (RI) Report documents the investigation activities that have taken place over the past ten years, and uses the data to identify source areas at Bradford Island, defines the nature and extent of the environmental contamination, and identifies the contaminants of potential concern (COPCs) for human health and contaminants of potential ecological concern (CPECs) in the media from the Upland and River OUs.

Landfill AOPC Summary of Contamination The Landfill AOPC is a former waste disposal site at the tip of Bradford Island that was used from the early 1940s until the early 1980s. Waste disposed of in the Landfill included: household waste, project-related wastes (grease, light bulbs, sandblast grit), electrical debris, up to 50 ballasts, broken glass, rubber tires, metal debris, wood debris, metal cables, asbestos containing building materials, burned debris, ceramic insulators, and mercury vapor lamps. Pesticide/herbicide mixing and rinsing of pesticide/herbicide application equipment also occurred near the Landfill. By 1982, the surface of the Landfill AOPC had been capped with soil, and another layer of soil was added in 1989.

Disposal and handling practices at the Landfill AOPC have impacted soil and/or groundwater with low levels of polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), metals, polychlorinated biphenyls (PCBs), pesticides, and herbicides.

Groundwater seeps discharge to the river along the northern boundary of the AOPC. The majority of the Landfill AOPC is flat and well vegetated, with no evidence of runoff or erosion. While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, however, if mass wasting were to occur on the steep slopes, the soils may reach the river.

Sandblast Area AOPC Summary of Contamination The Sandblast Area AOPC includes the area surrounding the former sandblast building on the eastern end of the site and consists of the following subareas:

- Former disposal area for spent sandblast blast grit
- Former transformer maintenance area east of the former sandblast building
- Former Hazardous Material Storage Area (HMSA) located east of the equipment building
- An inferred release of tetrachloroethylene (PCE) from an aboveground storage tank (AST) historically located in the vicinity of the current HMSA
- Laydown area used for current storage of industrial equipment and materials located along the north and south sides of the landfill access road

Spent sandblast grit was disposed of onsite in the area immediately east of the former sandblast building for an unknown period prior to 1994, and has resulted in the release of metals and butyltins into the soil. In November 1995, PCB-containing transformers were disassembled by the USACE at the paved parking area on the east side of the former sandblast building and

approximately 1 quart of PCB-containing oil was inadvertently released. Prior to 1993/1994, hazardous waste generated at the Bonneville Dam complex was stored at the former HMSA, which did not have a secondary containment system or berms. Historical waste handling in this area resulted in the release of metals, pesticides, TPH, and PAHs to nearby soils. The current HMSA does not appear to be a source of contamination, but prior to its construction, an approximately 300-gallon AST was formerly located in the vicinity. Several volatile organic compounds (VOCs) have been detected in soil, groundwater, and soil gas in the area. From these results, it has been inferred that there was a historical release from the AST formerly located in the vicinity of the current HMSA. The USACE stores industrial equipment and materials in the laydown area along the northern and southern portions of the Landfill access road. Soils in this area have become contaminated with metals, pesticides, PCBs, PAHs, TPH, and potentially other contaminants.

Stormwater runoff from impervious surfaces in the Sandblast Area AOPC drains to four catch basins that discharge to the Columbia River through two outfalls. It appears, however, that the majority of the runoff from asphalt immediately southeast of the former sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. This runoff travels down the slope to the equipment laydown area and adjacent Landfill access road, and onto a vegetated area between the Landfill road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates before reaching the river

Pistol Range AOPC Summary of Contamination The Pistol Range AOPC is located on the south side of Bradford Island and was used for small arms target practice from approximately 1950 through 1970. Surface soils became contaminated with low concentrations of lead and zinc. The topography of the area consists of a sequence of vegetated slopes and flat areas. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. However, when the Pistol Range AOPC was in use as a firing range, the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River.

Bulb Slope AOPC Summary of Contamination The Bulb Slope AOPC consists of a fan-shaped accumulation of glass and electrical light bulb debris that extends across approximately 1,900 square feet of a steep slope between the Columbia River and the Landfill access road. A thin layer of soil, up to 1 foot thick, overlies bedrock and became contaminated with low concentrations of PCBs, mercury, and lead. The well-vegetated slope exhibits no evidence of surface runoff, and mass wasting appears to be the only potential mechanism for transport of contaminated soil into the river.

River OU Summary of Contamination The River OU was identified in 2000, when numerous pieces of electrical equipment and other solid waste were discovered in the Columbia River along the north shore of Bradford Island. The removal of equipment and debris took place in December 2000 and in February and March 2002. Following delineation of the extent of sediment contamination, impacted sediments along the north shore of Bradford Island were dredged in October 2007. Residual contamination (including PCBs, PAHs, and possibly metals) in the sediment, as well as historically contaminated biota (e.g., fish and shellfish) may currently be sources of contamination. Transport of contaminants from the Upland OU, discussed above, may also be a current and/or historical source of contamination to the River OU.

Downstream sediment sampling appears to confirm that contaminated sediments are limited to the Bonneville Dam Forebay. Site-specific reference area soils and sediments were analyzed to determine naturally-occurring concentrations of inorganic constituents. Sediment and tissue samples from an upstream River Reference Area were analyzed to help distinguish site-related from non-site-related contributions of both inorganic and organic chemicals. The only significant limitation identified for the available data set is the fact that the Forebay smallmouth bass samples were collected in 2006, prior to the sediment removal action, and are therefore not representative of current Forebay conditions. Similarly, the lifespan of crayfish and sculpin is also long enough that the concentrations measured in these samples probably also incorporate exposure to pre-sediment removal conditions

Receptors and Exposure Pathways Potential on-site human receptors include outdoor workers who may be exposed to contaminated surface soils at the Upland AOPCs. Construction workers and excavation workers may be exposed to contaminated subsurface soils if they were to engage in soil-intrusive activities. Exposure routes related to soil include incidental ingestion, dermal contact, and outdoor inhalation of dusts and vapors. In the unlikely event that new wells are installed and untreated and unfiltered groundwater in the vicinity of either the Landfill AOPC or Sandblast Area AOPC is used for potable uses, the on-site workers may be exposed to contaminated groundwater by ingestion, dermal contact, and inhalation of vapors. At the Sandblast Area AOPC, the potential exists for intrusion of vapors from the subsurface (from soil gas and groundwater) into indoor environments, if enclosed structures were to be constructed here in the future. Upland OU contamination may be transported to the River OU via erosion, mass wasting, or groundwater discharge.

In the River OU, the primary human receptors are subsistence fishers, recreational fishers, and hypothetical consumers of unfiltered, untreated river water. The area where human receptors may potentially come in direct contact with contaminated sediments is near the mouth of Eagle Creek. Bioaccumulative chemicals in the River OU water and sediments may enter the food web when taken up into the tissues of edible species such as the crayfish and smallmouth bass. Recreational and subsistence anglers (adults and children) may then consume these edible species. Incidental ingestion of, or dermal contact with, river water is also considered.

Potential Upland OU ecological receptors include terrestrial plants, soil invertebrates, birds, and mammals. Exposure pathways include root uptake from, direct contact with, or ingestion of surface or subsurface soils. In the River OU, potential ecological receptors include benthic organisms, fish, and aquatic-dependent birds and mammals. Exposure pathways include ingestion of and dermal contact with surface water or sediments and the consumption of contaminated prey items.

Upland OU Risk Assessments Human health risk assessments (HHRAs) were completed through the problem formulation phase and ecological risk assessments (ERAs) were completed through Levels I and II (screening level) for each of the Upland AOPCs

At the Landfill AOPC, COPCs for human receptors in soil and groundwater included several metals, semivolatile organic compounds (SVOCs) including carcinogenic PAHs (cPAHs), chlorinated VOCs and TPH. Arsenic, cPAHs and chlorinated VOCs emerged as the primary carcinogenic COPCs. Only soil was identified as a medium of concern for ecological receptors at the Landfill AOPC. CPECs for terrestrial ecological receptors included antimony, chromium, lead, mercury, nickel, and high molecular weight PAHs (HPAHs). The areas with the highest

concentrations of these COPCs and CPECs included the mercury vapor-lamp test pit, lead hot-spot test pits #1 and #2, gully test pit, and pesticide/herbicide wash area.

At the Sandblast Area AOPC, the COPCs in soil were primarily a few metals, chlorinated VOCs, and cPAHs. The COPCs in groundwater were metals, VOCs, cPAHs, and some TPH fractions. The COPCs in soil gas were primarily chlorinated compounds. Lead may be a minor contributor to non-cancer hazards at the Sandblast Area AOPC. Arsenic, chlorinated VOCs, and cPAHs were the primary carcinogenic COPCs. CPECs in soil at the Sandblast Area AOPC included antimony, cadmium, chromium, lead, mercury, nickel, bis(2-ethyl hexyl) phthalate (B2EHP), and HPAHs. Areas with soil concentrations exceeding human health and ecological screening values occurred throughout the Sandblast Area AOPC, including the spent sandblast grit disposal area, around CB-1, the equipment laydown area, south of the current HMSA, and within the area where soils were identified as erodible in 2009.

The HHRA concluded that neither the Pistol Range AOPC nor the Bulb Slope AOPCs pose a threat to human health. For ecological receptors at the Pistol Range AOPC, lead in soil was the only CPEC. Areas with soil lead concentrations exceeding ecological screening values at the Pistol Range AOPC occurred behind the backstop and at the eastern corner of the former firing shed. CPECs at the Bulb Slope AOPC were limited to lead and mercury in soil.

In addition to the COPCs and CPECs identified in the screening evaluation and listed above, additional COPCs and CPECs were identified during the uncertainty evaluation (Appendix O), for reasons including, but not limited to, retention of degradation products, lack of SLVs, lack of SLVs that take into account bioaccumulation, and potential overland transport to the River (e.g., mass wasting/erosion).

River OU Risk Assessments Similar to the Upland OU, the HHRA and ERA for the River OU were completed through the problem formulation phase and through Levels I and II, respectively.

PCBs were identified as the primary COPCs in the River OU. In addition, a few metals, cPAHs and phthalates were retained as COPCs for sediment, crayfish tissue, and/or smallmouth bass tissue, although their contribution to risk is likely to be minor. They may contribute to human health risk through the pathway of crayfish and smallmouth bass consumption for both subsistence and recreational fish consumers. Although concentrations of metals in sediment were found to be less than Reference Area sediment, arsenic (in crayfish tissue) and mercury (in bass tissue) were identified in Forebay tissue that may be of concern for human health. PCBs were present in sediments, crayfish and smallmouth bass tissues at concentrations that may be of concern for human health. Five cPAH compounds were present in smallmouth bass tissues at concentrations that may be of concern to human health. PCBs, PAHs (both carcinogenic and non-carcinogenic), SVOCs, and TPH were detected in sediments at the mouth of Eagle Creek. Although direct contact with shallow sediments may occur in the vicinity of Eagle Creek, the human health risks at the River OU are associated primarily with consumption of smallmouth bass tissue, and secondarily crayfish tissue, although the observed concentrations are likely the result of historical body burden.

PCBs and a few metals were the only CPECs identified for ecological receptors in the River OU. PCBs in sediment were present at concentrations that may pose a risk to the benthic community exposed through direct contact. Cadmium, lead, mercury, and PCBs in sediment and sculpin tissue; cadmium in clam tissue; and mercury and PCBs in bass tissue were present at

concentrations that may pose a risk to upper trophic level fish and shellfish. Mercury and PCBs in sediment and sculpin and bass tissue, and PCBs in crayfish tissue were present at concentrations that may pose a risk to aquatic-dependent birds. Mercury and PCBs in sediment and tissue (sculpin and bass) were present at concentrations that may pose a risk to aquatic-dependent mammals. Although PCBs were present in crayfish tissue at concentrations identified as potentially a risk to aquatic-dependent birds, crayfish are not a driver species for birds due to the much higher concentrations of PCBs detected in sculpin and bass tissue (likely the result of historical body burden). PCBs in sediment were identified as an ecological concern at only three locations: stations P4 on the north shore of Bradford Island, P09 on the south side of the island (for birds only), and P43 at the mouth of Eagle Creek.

Given the low risk levels estimated for targeted Goose Island sediments samples relative to the risk levels estimated for the random Forebay for PCBs, and the absence of elevated PCB concentrations in Goose Island tissues, PCB concentrations in the targeted Goose Island samples are likely to have contributed minimally to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay. Concentrations of PCBs in Goose Island sediment may be of concern to human receptors although crayfish tissues did not show similar elevated risk levels. Although the Aroclor data for Goose Island demonstrated elevated ecological risk estimates for sediment, the available congener data, which are expected to provide a more accurate measure of total PCB concentrations, demonstrate acceptable risk levels for ecological receptors. Overall, although COPC and CPEC concentrations in media collected from the targeted Goose Island samples indicate low or acceptable risk levels, Goose Island will be maintained as part of the Forebay evaluation in the forthcoming FS in response to DEQ's request.

Recommendations Based on the screening level risk assessments at the Landfill and Sandblast Area AOPCs, implementation of one of two options is recommended for each of these AOPCs:

1. Perform a Feasibility Study (FS) to identify targeted soil removal or other remedial actions which will decrease residual concentrations to acceptable risk levels or
2. Perform a site-specific baseline human health risk assessment (BHHRA) and Level III baseline ecological risk assessment (BERA) to determine if risks to human and ecological receptors are unacceptable. If this option is selected, site-specific factors would be considered (i.e., absence of special-status species, AOPC size, contribution of background levels of inorganics, etc.).

No additional evaluation of potential human health risk is recommended for either the Pistol Range or Bulb Slope AOPCs. However, further action addressing potential ecological risk is recommended at both AOPCs - either in the form of a Level III BERA or remediation of the soils with elevated CPEC concentrations. If a Level III BERA is performed, site-specific factors would be considered (i.e., absence of special-status species, AOPC size, contribution of background levels of inorganics, etc.).

Neither a Level III BERA nor a BHHRA is recommended for the River OU. Instead, progression to a FS is recommended. Although a few other COPCs and CPECs were also identified, PCBs (through the consumption pathway) were identified as the primary risk drivers for both humans and wildlife. However, the PCB concentrations remaining in Forebay sediment (after the 2002 and 2007 removal actions) are inconsistent with PCB concentrations measured in Forebay tissue (most notably in smallmouth bass which were collected prior to the sediment removal action).

Monitoring of PCB concentrations in Forebay tissue may be recommended, to confirm that tissue concentrations are decreasing with time and that residual sediment concentrations are at acceptable levels.

Post-RI Activities As part of the pre-FS work for the River OU, additional bass, clam, and sediment samples were collected from the Forebay in September and October 2011, while additional bass were collected from the Reference Area in August 2011. In the Forebay, the bass were collected from areas north of Bradford Island, north of Goose Island, and south of Cascade Island. Bass were successfully collected at twenty-three locations in each of the areas; however, only nineteen samples from the Reference Area and twenty samples from the Forebay were analyzed based on project needs and goals. The co-located sediment and clam samples were collected at seven locations along the north-shore of Bradford Island in the areas suggested by DEQ as most likely to be influenced by Upland sources. Sediment and clam samples were successfully collected at all seven proposed sample locations; however, only six of the locations yielded enough clam tissue for the planned analysis. Sediment and tissue samples were analyzed for PCBs (Aroclors and 209 congeners), metals, PAHs, pesticides, butyltins, and SVOCs. This data will be presented in a subsequent document and will be used to verify the COPCs identified in the RI/RA for the River OU, as well as the COPCs originating from erosion or mass wasting evaluation of soils from the Upland OU. If the results indicate a potential source of contamination was overlooked, the list of sediment and tissue COPCs may be modified to reflect the new information. A more thorough evaluation of the potential for erosion and mass wasting of Upland soils will be conducted during the FS phase to support conclusions made regarding the likelihood and magnitude of the overland transport pathway.

1.0 INTRODUCTION

The Portland District of the United States Army Corps of Engineers (USACE) has conducted a multi-year effort to characterize and evaluate the contamination arising from historical USACE activities at Bradford Island in Oregon. Bradford Island is part of the Bonneville Dam complex, which is located on the Columbia River at river mile (RM) 146.1, approximately 40 miles east of Portland, Oregon.

The investigation around Bradford Island began as part of the evaluation of the former Bradford Island Landfill (the Landfill), which was used from the early 1940s to the early 1980s. In the course of numerous investigations that USACE and its contractors performed on Bradford Island and offshore since 1997, it became apparent that past upland and shoreline disposal activities had resulted in contamination of the site soil and groundwater, as well as the sediments of the adjacent river. Since 1996, USACE has been working with the Oregon Department of Environmental Quality (DEQ) to address the state's concerns regarding the site investigations and any associated cleanup activities.

In 2000 and 2001, discarded electrical equipment and debris were discovered in the river immediately north of Bradford Island. Three piles of debris were identified, which were removed in 2000 and 2002 (Appendix E of URS Corporation [URS] 2002a, URS 2002b). Following the equipment removal, sediments along the north shore of the island were characterized and the most highly impacted sediments were removed in October 2007 (Huang and Associates, Inc [HAI] 2007).

In 2007, the USACE submitted a Remedial Investigation/Feasibility Study (RI/FS) Management Plan (MP) (URS 2007a), which defined the objectives of the remedial investigation (RI) and described the work to be performed to meet the project objectives. Using the Data Quality Objectives (DQO) approach (United States Environmental Protection Agency [USEPA] 2006), the RI/FS MP identified data gaps and described plans for extensive data collection to fill the identified data gaps for the site soils and groundwater (Upland operable unit [OU]) and for the offshore sediments, surface water, and tissues of various aquatic species (River OU). The RI/FS MP also described how the collected data would be used to delineate the nature and extent of contamination, evaluate the potential risks to human and ecological receptors, and support decision-making needs. The USACE and the external stakeholders for the project, which are collectively referred to as the Technical Advisory Group (TAG) and include the DEQ, conducted extensive internal and external review of the RI/FS MP, and the document was finalized in September 2007.

The collection of additional data was completed by April 2009 in accordance with the requirements of the Upland OU Quality Assurance Project Plan (QAPP; URS 2008a), Upland QAPP Addendum (URS 2009a), River OU QAPP (URS 2007b), Revised Sculpin Analysis Strategy Technical Memorandum (URS 2009b), and In Water QAPP Addendum (URS 2009c). The suite of media sampled included upland soils, groundwater, soil gas, sediments, surface water, and tissue samples from multiple species, including clams (co-located with sediment samples), sculpin, smallmouth bass, and crayfish.

Two interim deliverables, the River OU Data Sufficiency Report (DSR) and the Upland OU DSR, were completed in November 2009 (URS 2009d,e). The DSRs evaluated the quality and quantity of the data available. The DSRs determined that the data gaps and data needs identified

in the RI/FS MP (URS 2007a) were filled and that the data to be sufficient and usable to complete the RI and associated human health risk assessment (HHRA) and ecological risk assessment (ERA).

This RI Report documents the investigation activities that have taken place over the past ten years, and uses the data to identify source areas at Bradford Island, defines the nature and extent of the environmental contamination, and identifies the contaminants of potential concern (COPCs) for human health and contaminants of potential ecological concern (CPECs) in the media from the River OU and Upland OU.

1.1 Report Objectives and Organization

The objectives of this RI report include:

- Identify source areas
- Identify current on-site upland source contribution to river sediment contamination
- Identify nature and extent of contamination in the upland and river areas
- Evaluate fate and transport of contaminants
- Perform a screening level (Problem Formulation) HHRA to identify COPCs which pose potentially unacceptable risk to human health.
- Perform a screening level (Phase I and II) ERA to identify CPECs which pose potentially unacceptable risk to ecological receptors.
- Determine which COPCs/CPECs in which portions of the site require additional risk assessment via a Baseline HHRA (BHHRA) and/or Level III Baseline ERA (BERA) to determine whether or not they need to be addressed in the subsequent feasibility study (FS).
- Determine which COPCs/CPECs in which portions of the site require no additional risk assessment and will be carried forward to the FS.

This report will provide the basis for the FS studies to be reported under separate cover, the objective of which will include:

- Evaluate whether source controls are necessary to address upland sources to sediment contamination
- Evaluate potential cleanup alternatives, both in the uplands and for sediment
- Determine Remedial Action Objectives (RAOs)
- Evaluate cleanup alternatives
- Recommend proposed cleanup remedies

This RI report is organized as follows:

Executive Summary

Section 1 – Introduction

Section 2 – Reviews Project Organization and Responsibilities

Section 3 – Reviews Site Background and Physical Characteristics

Section 4 – Presents Conceptual Site Model

Section 5 – Reviews the Historical Site Operations, Environmental Investigations, and Remedial Actions

Section 6 – Reviews Recent Site Investigations

Section 7 – Evaluates the Quality of the Data

Section 8 – Compares Site data to Reference Areas

Section 9 – Discusses Nature and Extent of Contamination

Section 10 – Discusses the Fate and Transport of Contaminants of Further Interest

Section 11 – Presents the Human Health Risk Assessment

Section 12 – Presents the Ecological Risk Assessment

Section 13 – Summary and Conclusions

Section 13 – References

Appendix A contains the project analytical database, Appendix B contains the field boring logs, Appendix C contains a photographic summary of the site, and Appendix D contains groundwater elevations (table and plots). Appendix E contains the analytical laboratory reports and Appendix F contains the data validation reports. Appendix G contains the historical data not included in the RI. Appendix H provides the individual polychlorinated biphenyl (PCB) congener data, and describes the calculation of total PCBs (as Arcolors and as congeners) and total polycyclic aromatic hydrocarbons (PAHs). Appendix I provides data summaries and statistics for each of the OUs and areas of potential concern (AOPCs). The screening level values (SLVs) are provided in Appendix J. Appendix K analyzes data sensitivity relative to the SLVs and Appendix L compare site data to reference area data. M and N present the HHRA and ERA screening tables, respectively. Appendix O presents the uncertainties in the HHRA and ERA. Appendix P provides the Responses to DEQ Comments on the Draft RI Report.

1.2 Site Description

Bradford Island is part of the Bonneville Dam complex, located on the Columbia River at RM 146.1, approximately 40 miles east of Portland, Oregon (Figure 1-1). The site is a multipurpose facility that consists of the First and Second Powerhouses, the old and new navigation locks, and a spillway with a capacity of 1.6 million cubic feet per second (cfs) (USACE 2000). Features of the Bonneville Dam complex are shown on Figure 1-2.

1.2.1 Site Overview

Site investigations on Bradford Island began with evaluation of the Landfill. The Landfill was used from the early 1940s until the early 1980s. The USACE informed the USEPA and the DEQ of the presence of the Landfill in 1996. The Landfill was added to the DEQ Environmental Cleanup Site Information (ECSI) database in April 1997, and the Bonneville Dam Project Manager (PM) signed a DEQ Voluntary Cleanup Agreement letter for the Landfill in February 18, 1998 under the DEQ Voluntary Cleanup Program (VCP). In 2004, USACE elected to

continue the Bradford Island project under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The USACE is currently working with the DEQ to address the state's concerns regarding this investigation and any associated cleanup activities.

Numerous investigations have been performed by the USACE and their contractors since 1997, focusing on two OUs, the Upland OU and the River OU (Figure 1-3). A review of site records for the Upland OU, including employee interviews, site environmental audits, and environmental investigations resulted in the identification of four AOPCs: the Landfill AOPC, Sandblast Area AOPC, Pistol Range AOPC and Bulb Slope AOPC (Figure 1-4). Contaminant source areas within the AOPCs are discussed in Section 4.0. The primary contaminants of interest (COIs) that have been identified in soil and/or groundwater in the four AOPCs include selected metals; PCBs; semivolatile organic compounds (SVOCs), including PAHs; butyltins; volatile organic compounds (VOCs); and a few pesticides/herbicides. A detailed description of the historical and recent soil and groundwater investigations and remedial activities is included in Sections 5.0 and 6.0, respectively. The COIs identified in offshore sediments include selected metals, PCBs, and PAHs.

Numerous dredge evaluations and other sediment studies/investigations were conducted in the Bonneville Dam Forebay since 1991. During the investigation of the Landfill, hydrographic and underwater dive surveys were conducted in October and November 2000 along the north shore of Bradford Island and numerous pieces of electrical equipment and other solid waste were discovered in the Columbia River adjacent to the Landfill. The removal of equipment and debris from the Columbia River along the north shore of Bradford Island took place in December 2000 and in February and March 2002 (Appendix E of URS 2002a, 2002b). Approximately 32 tons of solid waste was removed and disposed of off-site. Following delineation of the extent of sediment contamination, impacted sediment along the north shore of Bradford Island were dredged in October 2007 (HAI 2007). A description of the historical studies/investigations and dredging/removal actions is included in Section 5.0. In areas where historical data is representative of current conditions (i.e., in upland soils) it is used in this RI. In areas where historical data no longer represents currents conditions (i.e., river sediments) it is not used in this RI. Post-removal sampling that has filled upland data gaps and characterized conditions in the River OU after the sediment removal is discussed in Section 6.0. With the exception of few samples collected from areas that were subsequently dredged, all of this recent data is included in the RI data set.

1.3 Regulatory Initiative

Through Executive Order 12580, authorities under the CERCLA (42 United States Code [USC] 9601 et seq.) have been delegated from the President of the United States down to the Director of Civil Works of the Army. These authorities include the authority provided in CERCLA Section 104 to conduct removal and remedial actions in response to releases or threatened releases of a CERCLA hazardous substance or pollutant or contaminant, the authority provided in CERCLA Section 121 to select remedial actions to respond to such releases, and the authority to carry out response actions on federal facilities under CERCLA Section 120 as the lead federal agency. This authority to select and carry out response actions as the lead federal agency in accordance with CERCLA has been delegated to the Commander of the USACE Northwestern Division with respect to releases or threatened releases at Bradford Island. This includes the authority to sign decision documents or records of decision (RODs) for removal or remedial actions in accordance

with CERCLA and the National Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] Part 300) at Bradford Island.

The USACE is conducting the RI/FS at the Bonneville Lock and Dam Project, and therefore the authority the USACE has to fund the project is through its operations and maintenance funds for the Project.

The DEQ and CERCLA have the same objectives regarding protection of human health and the environment, and it is the goal of the USACE and the project delivery team (PDT) to meet these broad objectives. The PDT is working directly with DEQ to ensure that appropriate Oregon cleanup regulations and DEQ guidance documents are being followed. However, in attempting to follow both DEQ and CERCLA, specific methodologies and guidance may not completely concur. The PDT, in conjunction with the independent technical review (ITR) team, will use the most current, scientifically defensible methods as required by USACE guidance (Department of Defense [DoD] Environmental Data Quality Workgroup [EDQW] 2009) throughout this project to develop investigation and cleanup strategies. These methods will meet all Federal requirements, and to the extent possible also conform to DEQ guidance.

USEPA has elected not to be directly involved with this project; however, the PDT will keep USEPA informed of project progress as needed.

1.4 Project Schedule

The following table presents the current and potential future project milestones with expected completion dates. Depending upon the evaluation of FS data needs, further investigations may be necessary, which would affect the estimated completion dates for subsequent project milestones.

Project Milestones	Estimated Date
RI Report, incl. Level I and II ERA and HHRA Reports	November 2010
Level III BERA and BHHRA Report for Selected Upland AOPCs	2011
FS Data Needs – QAPP and Data Collection	2011 & 2012
FS Report	TBD
Proposed Plan	TBD
ROD	TBD

Notes:
TBD – To Be Determined

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

This section describes key USACE roles on this project, as well the roles of other federal agencies, state agencies, Indian Tribes, and contractors.

2.1 USACE Project Manager

The USACE PM, Joseph M. Dasso, will have project management authority throughout the life of the project and is responsible for overall management and execution of the project, including project quality, cost, and schedule. Specific tasks include:

- Manage overall project and project funding.
- Communicate and coordinate with Tribal governments, agencies, and stakeholders, including the TAG, public, DEQ, USEPA, United States Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), Columbia River Inter-Tribal Fish Commission (CRITFC), Oregon Department of Human Services (DHS), Oregon Department of Fish and Wildlife (ODFW), Washington State Department of Ecology (Ecology), and Washington Department of Health (WDOH).
- Document all communication with stakeholders and tribal governments.
- Initiate and participate in TAG, public, community involvement committee (CIC), and stakeholder meetings.
- Communicate with media, including reporters.
- Lead communication and coordination with Division and Headquarters.
- Convene and coordinate with hazardous, toxic, and radiological waste (HTRW) committee as necessary.
- Make decisions affecting project after consulting with PDT.
- Participate in weekly PDT coordination meetings.
- Ensure that actions satisfy and conform to regulatory requirements.

2.2 USACE Technical Lead

The USACE Technical Lead, Mike Gross, will assist the PM as needed throughout the life of the project. Specific tasks include the following:

- Manage the PDT.
- Act as a main point of contact for contractors, and initiate and manage contractor task orders.
- Initiate and participate, as necessary, in weekly team coordination meetings, as well as in technical, TAG, and other meetings.
- Assist the PM as necessary.
- Act as the PM as needed.

2.3 USACE Technical Team

The USACE Technical Team is composed of technical experts from both the Portland and Seattle Districts. In addition to the USACE PM and USACE Technical Lead, the Technical Team includes John Wakeman, Catherine Martin, and Kenneth Duncan. Disciplines include risk assessment, biology, hydrogeology, chemistry, and environmental engineering. The USACE Technical Team is led by designated task leaders who are assigned on a task-by-task basis. The task leaders direct the PDT. The USACE Technical Team are supplemented with additional USACE resources as needed.

The Technical Team will work closely with all contractors. The task leads will coordinate with the PDT, the PM, and/or the Assistant PM to help resolve all technical issues.

2.4 USACE Independent Technical Review

ITR is the process that confirms the proper selection and application of established criteria, regulations, laws, codes, principles, and professional procedures to ensure a quality product. Technical review confirms the effectiveness of the product and the use of clearly justified and valid assumptions and methodologies. Technical review also includes a comprehensive interdisciplinary review consistent with the established review budget. For this project, the ITR shall consist of discipline-specific review and interdisciplinary coordination review by senior staff or appropriate peer review by those who were not primary designers. All documents produced for this project will undergo ITR.

The ITR team consists of senior technical staff at the Portland District, the Seattle District, and Environmental and Munitions Center of Expertise in Omaha, Nebraska. Specific reviewers include Terry Walker, Sam Bass, Thomas Georgian, Chung –Rei Mao, and Sandy Fry. Other reviewers may be assigned on a task-by-task basis by the task leads.

2.5 Contractors

The prime contractor performing this work is URS. Mike Powell, of the Portland, Oregon office, is the URS PM. He is assisted by specialists from multiple disciplines, including risk assessment, biology, geology, hydrogeology, chemistry, and engineering. The URS team is led by designated task leaders who are assigned on a task-by-task basis. The task leaders report to the URS PM who works closely with the USACE Technical Team. The URS PM will coordinate with the PDT, the USACE PM, and/or the Assistant USACE PM to help resolve all technical issues.

2.6 Technical Advisory Group

Natural resource trustees are federal, state, or Tribal officials who may act on behalf of the public as trustees for natural resources. Natural resources are land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources controlled by the United States, any state or local government, or any Indian Tribe (40 CFR 300.5 and CERCLA §107[f][1]). The federal trustees actively participating in this project include the USACE, USFWS, and NOAA. The state trustees include DEQ, ODFW, DHS, and Ecology. The federal and state trustees are invited to participate in regularly scheduled TAG meetings and given the opportunity to review and provide detailed comments on all technical work completed for this project. Comments provided by the federal and state trustees will be evaluated and addressed by the PDT.

Several Indian Tribes have interests in the Columbia River and the Bradford Island site, including the Yakama Nation, the Warm Springs Tribe, the Cowlitz Tribe, the Chinook Nation, the Nez Perce Tribe, and the Confederated Tribes of the Umatilla Reservation. Tribal interests include potential sites with cultural significance (National Historic Preservation Act [NHPA] Section 106) as well as treaty fishing rights in "usual and accustomed" areas. These areas may extend beyond a Tribe's reservation land and apply to landless Tribes.

The federal trust responsibility involves recognizing trust obligations and trust resources. In order to exercise trust responsibility it is important to obtain Indian Tribal views of trust and treaty responsibilities related to USACE actions. These responsibilities are exercised in accordance with provisions of treaties, laws, executive orders, and the Constitution of the United States when the USACE implements or takes an action that may affect a Tribal interest. In order to effectively develop a relationship with the Tribes, the PDT will consult with each Tribe as a sovereign nation on matters related to trust and treaty responsibilities. The Tribes are invited to participate in regularly scheduled TAG meetings and given the opportunity to review and provide detailed comments on all technical work completed for this project. Comments provided by the Tribes will be evaluated and addressed by the PDT. Specifically, the USACE will:

- Operate within a government-to-government relationship with federally recognized Indian Tribes
- Consult, to the greatest extent practicable and permitted by law, with Indian Tribal governments before taking actions that affect federally recognized Indian Tribes
- Assess the impact of agency activities on Tribal trust resources and assure that Tribal interests are considered before the activities are undertaken
- Remove procedural impediments to working directly with Tribal governments on activities that affect trust property or governmental rights of the Tribes
- Work cooperatively with other agencies to accomplish these goals

Consultation efforts will be coordinated through the USACE Portland District Tribal Liaison.

3.0 SITE BACKGROUND AND PHYSICAL CHARACTERISTICS

The Portland District of the USACE has conducted a multi-year effort to characterize and evaluate the potential environmental contamination arising from historical USACE activities at Bradford Island in Oregon. Bradford Island is part of the Bonneville Dam complex, which is located on the Columbia River RM 146.1, approximately 40 miles east of Portland, Oregon. This section describes the Bonneville Dam complex, its general location, history, facility operations, and regulatory status, as well as a brief description of the each of the OUs and AOPCs which are the subject of this RI.

3.1 General Location and Description

The Bonneville Dam and Lock Project (the Project) is the most downstream dam within the Columbia-Snake River navigation system that consists of eight locks and dams (Figure 3-1). The Bonneville Dam is at the upper limit of tidal influence from the Pacific Ocean, about 145 miles upstream from the mouth of the Columbia River and 40 miles east of Portland-Vancouver.

The dam is located at 45° 38’ 27’’ N - 121° 56’ 31’’ W. Bonneville Lock and Dam create a 48-mile-long reservoir from the Bonneville Dam upstream to the Dalles Dam, called the Bonneville Pool. The Columbia River at the Bonneville Dam is divided into three channels by two islands: Bradford Island and Cascade Island. The tailrace for the First Powerhouse forms one channel, the spillway forms the middle channel, and the tailrace channel for the Second Powerhouse forms the third channel (Figure 1-2). The spillway, consisting of 18 gates, each 50 feet wide, is located between Bradford and Cascade Islands, spanning the middle channel. The spill gates are raised to allow excess river flow to pass under them at a depth of about 50 feet below the upstream water surface.

The major features of the Project include the spillway, two powerhouses, two navigation locks (one lock is no longer in use), and a fish hatchery (Figure 1-2). The fish hatchery, main office, and navigation lock visitor center are located on the Oregon shore of the Columbia River. A warehouse and automotive garage facility, and navigation lock support facilities are located on Robins Island, located between the Oregon shore and Bradford Island. The major features on Bradford Island are the Bradford Island visitor center, fish ladders, the service center building, and the equipment building. Although the sandblast building is shown in Figure 1-2, it was structurally damaged in a storm a couple years ago and was demolished within the last year. Another fish ladder is located on Cascade Island, and a third visitor center is located on the north shore of the Columbia River in Washington State.

The old navigation lock is adjacent to the First Powerhouse and is no longer in use. The upstream side of the old navigation lock consists of an end sill (where the lock doors are located) that extends from the riverbed to an elevation of 40 feet above mean sea level (msl). The current navigation lock (Figure 1-2) is located immediately south of the old navigation lock and has an end sill that extends to an elevation of 51 feet above msl.

An authorized federal navigation channel in this reach of the river is 300 feet wide and 27 feet deep, although the depth is currently maintained at 17 feet (USACE 1991). Limited dredging is necessary to keep the channel to the maintained depth near the dam. Bathymetric surveys conducted by USACE indicate that the pool near the Bonneville Dam (within the spillway forebay) is up to 100 feet deep.

3.1.1 Regional Geology

The Project is located in the Columbia River Gorge, a 50-mile canyon that cuts through the Cascade Range physiographic province (Orr and Orr 1999). The canyon has formed through time as the Columbia River incised through various geologic formations, including the Western Cascade Group, the Columbia River Basalt Group, and the High Cascade Group, in response to the uplift of the Cascades over the last 2 million years (Beeson and Tolan 1987).

Three bedrock formations are present near Bonneville project: the Ohanapecosh Formation (also referred to as the Weigle Formation), the Eagle Creek Formation, and the Columbia River Basalt Group (Holdredge 1937; Wise 1970). The Ohanapecosh Formation consists of late Oligocene-aged volcaniclastic siltstones and sandstones with minor conglomerates. As much as two-thirds of the clasts in this formation consist of glass fragments. The fragments have subsequently altered to a dominantly clay mineral assemblage, greatly weakening the formation.

Folding and faulting have significantly disturbed the Ohanapecosh Formation. Bedding generally strikes northeast and north, with a dip of 5 to 20 degrees to the east and southeast. Two predominant fault/shear zone orientations have been identified in association with the development and construction of Bonneville Dam. They include northwest-striking features dipping moderately to steeply to the northeast and northeast-striking features dipping gently to moderately to the northwest. These features do not continue into the overlying Eagle Creek Formation, indicating that fault movement ceased before the Eagle Creek sediments were deposited. No outcrops of the Ohanapecosh formation are found at the site.

The Eagle Creek Formation overlies the Ohanapecosh Formation, and is differentiated primarily by larger clast size and lack of alteration. The Eagle Creek Formation consists primarily of sandstones and conglomerates, with individual units of sedimentary tuffs. Bedding in the unit is near horizontal. The Eagle Creek Formation crops out near river level near the site.

The Columbia River Basalt Group disconformably overlies the Eagle Creek Formation. Flood basalts of this group are Miocene in age and originated from a series of fissures in eastern Washington, Oregon, and Idaho. In the vicinity of Bonneville Dam, the basalts have been uplifted several hundred feet above the current river level.

Two landslides have significantly modified the topography in the vicinity of the site (Sager 1989). Those slides are believed to have been at least partly the result of catastrophic floods during the late Pleistocene that scoured away the talus slopes from the Columbia Gorge. That action over steepened the walls of the Gorge and effectively removed the buttressing effect of the talus slopes. Scouring also exposed the clay-rich Ohanapecosh Formation, which may have contributed to the landslides. The Tooth Rock Landslide is a large rotational block failure that originated on the Oregon side of the Gorge, south of Bradford Island. The slide is reported to have incurred only rotational movement, without lateral expansion. Large slide blocks of the Eagle Creek Formation contributed to the formation of Bradford Island. Because of the slide's rotational nature, the blocks are relatively undisturbed and form a local, but variable, bedrock surface beneath the Bradford Island. Portions of the Tooth Rock slide block extend into the Columbia River and are submerged. Therefore, the river bottom in the immediate vicinity of Bradford Island consists of Eagle Creek Formation overlain by a thin layer of sands and silts that have been deposited in lower velocity areas.

A second large-scale landslide in the area is known as the Bonneville (Cascade) slide. The slide originated on the Washington side of the Gorge between 400 and 800 years ago. The toe of the landslide forms the northern abutment of the Second Powerhouse. Debris from the slide have been observed to overlie the Tooth Rock slide on portions of Bradford Island.

The Tooth Rock slide blocks at the site are also overlain by up to 30 feet of alluvium associated with Holocene to recent flooding of the Columbia River. The alluvium consists of silty sands and gravels that contain increasing amounts of Eagle Creek Formation clasts with depth.

3.1.2 Climate

A meteorological observation station has been in operation at the Project since July 1, 1948. During a 57-year period of meteorological records (1948 through 2005), the station recorded average summer daytime maximum temperatures of 65.8 degrees Fahrenheit (°F) and average winter daytime maximum temperatures of 35.4°F (Western Regional Climate Center 2002). Temperature extremes at the Bonneville Dam have varied from a low of (-5°F) on January 31, 1950, to a high of (107°F) on August 18, 1977.

The average annual precipitation at the Project for the period of record is 77.05 inches. December and January are the months with the highest precipitation rates, and July is the month with the lowest (Western Regional Climate Center 2002). Recorded daily maximum precipitation rates have exceeded 1 inch for every month, with the maximum daily rate of 5.05 inches recorded on November 25, 1999. Average annual snowfall at the dam is 17.7 inches, normally occurring from November through March.

3.1.3 Groundwater/Hydrogeology

Occurrences of shallow groundwater have been evaluated as part of the previous environmental investigations near the former Landfill and the former sandblast building (eastern tip of Bradford Island). Additional groundwater information was generated as part of this RI. Based on these investigations, two shallow stratigraphic units exist on the eastern tip of Bradford Island:

1. **Fill/alluvium.** This unit consists of silty to clayey sands and ranges from 15 to 30 feet in thickness. At depth, there are increasing bedrock clasts. This unit occurs beneath the upland portion of the site and pinches out near the northern shore of Bradford Island.

2. **Bedrock.** The bedrock unit consists of a slide block emplaced from the Oregon side of the river. The block is composed of the Eagle Creek Formation, which consists primarily of sandstones and conglomerates. The uppermost 2 to 5 feet of this unit is fractured.

Groundwater on the eastern tip of Bradford Island appears to be perched in the alluvium above the less-permeable Eagle Creek slide block. Where the fractured bedrock crops out on the north shore of the island, seeps form in the winter months. The slide block forms the base of the river near the island, with no to little sediment thickness found on top of the slideblock.

Appendix D summarizes hydrologic information collected from the on-site monitoring wells. Based on the horizontal hydraulic gradient measured in the fill/alluvium, the direction of groundwater flow beneath the Landfill AOPC is to the north (Appendix D, Figures D-1 through D-4). Horizontal hydraulic gradients between MW-2 and MW-5 in the Landfill AOPC range from 0.10 to 0.13 foot per foot (Appendix D, Table D-2). Measured hydraulic conductivities in

the fill/alluvium beneath the Landfill AOPC based on slug tests range from 14 to 320 feet per day (URS 2004b). Based on a water balance calculated for the former Landfill, approximately 61 percent (%) of the precipitation that falls on the Landfill AOPC footprint percolates to groundwater and discharges either along the north shore of Bradford Island as seeps or offshore of Bradford Island (URS 2004b). One of the monitoring wells (MW-8) is completed in the bedrock beneath the Landfill AOPC and groundwater elevations measured in this well in April 2008 and May 2002 are lower that the adjacent pool elevation (Appendix D, Table D-1). This suggests that in Spring, the direction of groundwater flow in the bedrock aquifer is downward (although it is upward at other times of year).

At the Sandblast Area AOPC, groundwater flow is to the north and northwest (Appendix D, Figure D-5 through D-8). Horizontal hydraulic gradients between MW-11 and MW-115 (to the north) range from 0.10 to 0.11 foot per foot and between MW-11 and MW-14 (to the northwest) range from 0.07 to 0.08 foot per foot (Appendix D, Table D-2). Measured hydraulic conductivities beneath the Sandblast Area AOPC based on slug tests range from 0.02 to 285 feet per day, indicating significant heterogeneity in this area.

3.1.3.1 Drinking Water - Bonneville Lock and Dam Project

No active drinking water wells are located on Bradford Island. Water supply well DW2, which is located on the eastern side of Bradford Island (Figure 3-2), was used for drinking water until 2000 (Perletti, pers. comm. 2010). The USACE decommissioned well DW2 in 2008.

Hatchery Wells H1, H2a, H3, H4, H5, H6 and H7 are located on the eastern end of Robins Island (Figure 3-2). The hatchery wells were installed between 1986 and 1991 to replace wells that were abandoned during the construction of the new navigation lock. The groundwater is extracted from a former alluvial unit that was buried by the Tooth Rock landslide. The alluvium overlies the Ohanapecosh Formation in this location and is up to 100 feet thick (Scofield 1998). These wells provide water to the hatchery and, either individually or combined, also provide drinking water to the Project (Perletti, pers. comm. 2010).

Water supply wells DW1 (also referred to as PW1 and WW-1794) and DW5 (also referred to as PW2 and WW-1800) are located on the eastern end of Robins Island (Figure 3-2). Both DW1 and DW5 historically provided drinking water to the Project (McCavitt, pers. comm. 2001). The USACE stopped using wells DW1 and DW5 several years ago for drinking water use as the wells were going dry; however, the USACE has not yet decommissioned the wells (Perletti, pers. comm. 2010).

Water supply wells DW3 and DW4, which are located on Cascade Island and the Washington shore, respectively, are currently supplying drinking water to the Project (Perletti, pers. comm. 2010). Potential releases to groundwater from Bradford Island should not pose a threat to these populations due to the lack of hydraulic connection to the perched water-bearing unit beneath the island.

3.1.3.2 Drinking Water – Project Vicinity

The population within a 4-mile radius relies on municipal water supplies taken from groundwater supply wells (Leland, pers. comm. 2001). The Columbia River hydraulically separates these populations from Bradford, Cascade, and Robins Islands. Potential releases to groundwater from Bradford Island should not pose a threat to these populations due to the lack of hydraulic connection to the perched water-bearing unit beneath the island.

3.1.4 River Hydrology

Flow within the Columbia River is modified by the operations of several federal and non-federal dams. Bonneville Dam at RM 146.1 is the dam farthest downstream on the Columbia River. Hydrologic conditions immediately upstream and downstream of the dam are the primary focus of this section; however, regional hydrology is addressed given its influence on local hydrologic processes and the Columbia River's evolution.

3.1.4.1 Regional Hydrology

The Columbia River drains an area of 259,000 square miles and is ranked seventh in length and fourth in stream flow among United States rivers. It flows 1,243 miles from its headwaters in the Canadian Rockies of British Columbia, across Washington State, and along the border of Washington and Oregon to the Pacific Ocean (Figure 3-1). There are 11 dams on the Columbia River's mainstem in the United States and 162 dams that form reservoirs with capacities greater than 5,000 acre-feet in the United States and Canadian parts of the basin (United States Geological Survey [USGS] 1996).

Climate in the Columbia River Basin varies considerably, but river hydrology is dominated by snowmelt from high-elevation areas, with the majority of annual flow occurring between April and July. High flows also occur between November and March, caused by heavy winter precipitation (Northwest Power and Conservation Council [NPCC] 2004).

All of the major dams and reservoirs within the basin operate in coordination with each other to manage floods, control fish migration, and produce power. The general operating year for the dams and reservoirs within the basin is divided into three periods:

- September through December – A fixed reservoir drawdown occurs, since a forecasted volume of runoff that will occur in the spring is not yet available. Flows are managed to enhance the spawning of chum salmon below Bonneville Dam.
- January through mid-March to April – A variable drawdown occurs to meet the forecasted volume of the spring runoff based on snow pack measurements. Water must be present in April for juvenile fish migration.
- April through August – Refill season; the reservoirs are managed in an effort to fill the reservoirs and allow fish migration.

3.1.4.2 Local Hydrology

Most technical publications concerning the Columbia River focus on the basin and subbasins, specifically as they relate to water quality and specific habitats. Publications addressing details of individual hydrologic inputs in the immediate vicinity of Bonneville Dam do not appear to be readily available. The position of the Columbia River as a border between Oregon and Washington may contribute to the disjunction of available information. A series of subbasin plans and water quality reports were reviewed to obtain general information about the Columbia River Basin within the area of interest, which runs approximately from RM 142 (Pierce and Ives Islands) to RM 148 (Bridge of the Gods).

Bonneville Dam is considered a run-of-river project. Run-of-river projects, by definition, have limited storage and were developed primarily for navigation and hydropower. These types of

projects pass water at the dam at nearly the same rate it enters the reservoir, with an average variance of water level behind the dam of 3 to 5 feet.

The tailwater elevation below Bonneville Dam varies in direct relationship to the river discharges, and ranges from about 7.0 feet above msl at a river flow of 70,000 cfs to 36.3 feet above msl at a river flow of 660,000 cfs (USACE 1998). From Bonneville Dam to the ocean, the slope of the Columbia River is very flat and subject to tidal action. The daily tidal influence on water level during low water periods ranges from 1 to 2 feet at the dam (Washington Department of Fisheries [WDF] et al. 1990).

Within the Columbia River Basin are numerous subbasins formed by tributaries of the mainstem river. Although the layouts of the subbasins in their entirety extend beyond the area of interest, they each contain tributaries of the Columbia, as identified below, within the area of interest.

Hydrologic inputs immediately upstream of the dam include Ruckel and Eagle Creeks on the Oregon side. Washington maps do not indicate any named creeks immediately above the dam, although drainage features are presumed to exist. Hydrologic inputs immediately downstream of the dam include Tanner and Moffett Creeks on the Oregon side with Greenleaf and Hamilton Creeks contributing on the Washington side.

Streams draining the Oregon side of the Columbia River Basin (within the area of interest) originate and flow through the Hatfield Wilderness, a 39,000-acre portion of land managed by the United States Forest Service (USFS). Although streams discharging to the Columbia originate and primarily flow through the protected wilderness, they also pass through the privately held and often developed properties located along the waterfront. Development such as roadways and railroads with riprap bisect the lower reaches of the tributaries and are presumed to have the greatest influence on the flow rate and water quality at the point where the tributaries join the Columbia.

Urbanization of the land along the Columbia on the Washington side has substantially altered original drainage and subsequent hydrologic inputs. A major highway, railroad, and associated riprap also bisect tributaries along the riverfront on the Washington side.

Forestry is a major industry upstream and downstream of the dam, especially in Washington. Timber practices are typically clear-cut and slash-and-burn, subject to Forest Practices Act regulations of both states (WDF et al. 1990). The significance of this industry, and to a lesser degree agriculture, is its effect on runoff and subsequent water quality. A damaged or destroyed riparian buffer, due to deforestation and agriculture, can substantially alter the morphology of streambeds and, in some cases, whole drainage basins. An example would be increased flow rates, which can result in aggressive streambed scour, increased turbidity, elevated concentrations of dissolved minerals, and habitat destruction. Not only is the tributary being affected but also subsequent discharge can potentially influence water quality, habitat, and flow in the mainstem.

3.1.5 Site Ecology

This section describes the habitats present at Bradford Island and identifies Endangered Species Act (ESA)-listed species and other important non-listed fish that may occur or have the potential to occur in the area.

3.1.5.1 Habitats

A description of the habitat at each Upland OU AOPC and a description of the aquatic habitat of the River OU are provided below. Appendix C contains a photographic summary of each Upland OU AOPC and the River OU.

Landfill AOPC – Upland meadow and shrub/forest fringe communities occupy the Landfill AOPC. This area once served as a temporary nursery for landscape plants used at Bonneville Dam and adjacent facilities. Not all of these ornamental plants were removed and some have survived. Adjacent to the Landfill AOPC is a larger area of conifer-dominated forest. The upland meadow habitat that occupies the surface of the Landfill AOPC has been disturbed by various field investigative activities (i.e., test pits, drilling operations) but has since been recolonized by the invasion of surrounding herbaceous vegetation.

The shrub and forest fringe area is characterized by rocky outcrops at the edges of the island and at the margin of the flat meadow area adjacent to the forested habitat. The substrate consists of a mixture of soils, rock that may have been placed in some areas, and what appear to be natural rock outcrops. The Landfill AOPC terrain is flat at the top and slopes steeply to the north and east into the Columbia River. The slopes are more densely vegetated with shrubs and trees than the flatter areas adjacent to the meadow.

The upland conifer forest in the Upland OU Reference Area appears to be the least disturbed habitat on the island, as it is composed of mostly native species. This forest is apparently relatively young; USACE photographs from the 1930s show much smaller trees. It is likely that this forest was naturally seeded rather than planted. No stumps are present, indicating that past logging either did not occur, or was followed by recontouring the land that included removal of stumps. The larger trees are up to 1.5 feet in diameter at 4.5 feet above the ground, and form a closed canopy. The substrate in the forest area consists of relatively thin topsoil and rocky outcrops. Dead and downed woody material is common.

At the eastern tip of the island, a small (less than 0.25 acre) opening is located at the top of the cliffs that form the shoreline. A thin veneer of soil covers bedrock in this area. A smattering of the shrubs similar to the forest habitat described above are present, but the area is mostly open.

Sandblast Area AOPC – The Sandblast Area AOPC generally consists of a north facing slope with numerous topographic/habitat complexities. Upslope of the former sandblast building is a relatively undisturbed and densely herbaceously vegetated hill slope. Below the upper hill slope is a relatively flat and paved area around the former sandblast building. Downslope (to the north-northeast) of the former sandblast building and the adjacent paved area is a short, steep hill with a shrub/forest community leading to the flat, unvegetated equipment laydown area and the paved road leading east to the Landfill AOPC. Downslope (to the northwest) of the former sandblast building is a relatively flat, herbaceously vegetated area, followed by a recently disturbed slope, then a paved road. Excavation and filling activities on the northwest slope in 2009 removed vegetation and exposed bare, erodible soils at the ground surface. During the following year, the disturbed area has naturally revegetated and is currently vegetated with a dense scrub/shrub community (see the photos in Appendix C).

Pistol Range AOPC – Once the Pistol Range AOPC ceased being used for small arms practice in the late 1960s or early 1970s, the firing range was recolonized by the invasion of surrounding herbaceous vegetation. The topography of the area consists of a series of cuts and fills, resulting

in a sequence of slopes and flat areas. Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation. An upland meadow community, similar to the Landfill AOPC meadow community, covers the firing range. The hillside behind the backstop is moderately steep (15 to 30 degree slopes) and is densely vegetated with herbaceous vegetation and shrub/forest fringe communities. Along the southern portion of the firing range and south of the access road, a densely vegetated scrub/shrub community is present.

Bulb Slope AOPC - The Bulb Slope AOPC consists of a steeply sloped area between the Landfill access road and the Columbia River on the north side of Bradford Island. The substrate consists of a mixture of soils, rock that may have been placed in some areas, and what appear to be natural rock outcrops, all of which is underlain by underlain by siltstone bedrock. The majority of the Bulb Slope AOPC is herbaceously vegetated and/or covered with organic debris.

Aquatic Habitat – Bradford Island (Upland OU) does not contain any wetlands, lakes, or ponds that would have the potential to be considered sensitive environments. However, aquatic habitats include a portion of the Columbia River adjacent to Bradford Island, consisting of the pooled area behind the Bonneville Dam complex, known as the Bonneville Dam Forebay (River OU). The area of this portion of the River is approximately 230 acres.

Water depth behind Bonneville Dam is variable. The area between Bradford Island and Cascade Island extends to a depth of approximately 100 feet. Based on historic photographs and USACE hydroacoustic sounding data, a submerged shelf appears to be adjacent to the north side of Bradford Island at a depth of about 30 feet below pool level. This shelf appears to be about 50 feet wide, parallel to the north shore of the island. The shelf could be critical habitat for ESA-listed salmonids. Shallow water (20 feet deep or less) also occupies a band approximately 50 feet wide along the south shoreline of Bradford Island.

Hydraulic modeling of the waters near Bradford Island was conducted by the USACE (Langsley 1999). This modeling indicates that a large eddy forms behind the dam and creates a reverse current flow next to Bradford Island. This reverse flow appears to attract adult salmonids exiting the fish ladder on their way upstream and may result in the fish being swept back over the dam (Langsley 1999). Introduced fish species may be present in the Forebay for prolonged periods throughout the year and are popular recreational species with a recognized societal value.

3.1.5.2 ESA-Listed Species & Other Important Fish

The list of sensitive species with potential to occur at the Bonneville Dam Forebay is provided in Table 3-1. The table is an updated summary of the more detailed information presented in the Biological Characterization (Appendix F) of the Draft Supplemental Site Inspection (SSI) (URS 2000). The list of species was originally derived from Oregon Natural Heritage Program (1999) data for species recorded within 5 miles of the Landfill, correspondence from USFWS (1999) and National Marine Fisheries Service (NMFS; 2000), information from USACE personnel, reference books, and reports of studies focused on protected species in the Bonneville Dam vicinity. The status of the species in the list was updated based on the Threatened, Endangered, and Candidate Fish and Wildlife Species in Oregon (USFWS 2009) and the Oregon Natural Heritage Program Rare, Threatened and Endangered Species of Oregon list (Oregon Natural Heritage Program 2007).

The special-status (federally and state-listed threatened) fish and wildlife species that are known to occur or could potentially occur at the site are described below. In addition, this section also presents a brief discussion of non-listed important fish species that may occur in the Forebay.

3.1.5.3 Fish Species

The Lower Columbia River is characterized by warmer, slower waters than the upper reaches, and this region consequently supports a larger diversity of native resident fish species such as the following non-listed fish: white sturgeon (*Acipescer transmontanus*), longnose suckers (*Catostomus catostomus*), and minnows (i.e., chiselmouth [*Acrocheilus alutaceus*]). Other native species that are found throughout the Columbia River include special-status trout (i.e., steelhead [*Oncorhynchus* spp.] and bull trout [*Salvelinus confluentus*]), non-listed trout (i.e., cutthroat trout [*Oncorhynchus clarki clarki*]), non-listed whitefish (i.e., mountain whitefish [*Prosopium williamsoni*]), and a variety of non-listed sculpins (*Cottidae*) (Troffe 1999; USACE 2001).

Special-status anadromous fish species that have the potential to be present in the Bonneville Forebay are listed Table 3-2. Ten of the 12 evolutionarily significant units (ESUs) shown in Table 3-2 have the potential to be present near Bradford Island as juveniles, adults or both. The Columbia River near Bradford Island is used by these species primarily as a migratory route between upstream spawning areas and the Pacific Ocean. The listed ESUs fall into two juvenile life-history strategies: "ocean-type" that rear in freshwater for only a few weeks to a few months before migrating to the estuary/ocean during their first year of life, and "stream-type" that spend at least a year rearing in freshwater prior to their downstream migration to the ocean. The Biological Assessment for Anadromous Fish Species and Steller Sea Lion Essential Fish Habitat (USACE 2007) provides additional information as well as a general overview of the life history and status of each ESU and describes when adults and juveniles would be expected to occur near Bradford Island.

Adult salmon typically nearly cease feeding once leaving the Columbia River estuary on their upstream migration. Adult steelhead migrating upstream feed to a limited extent. Juvenile salmon and steelhead feed on their downstream migration. Juveniles feed on aquatic invertebrates and small fish. As noted above, several listed and candidate anadromous fish pass through the lower Columbia River on their journeys between spawning areas and the ocean. The residence time for anadromous fish near Bradford Island is expected to be minimal, but native and introduced resident species may forage at the Bonneville Dam Forebay and many of these fish are popular recreational species.

Popular recreational fish species such as largemouth (*Micropterus salmoides*) and smallmouth (*M. dolomieui*) bass are common to the lower Columbia River and could reside in the Bradford Island vicinity. Other introduced fish species such as catfish (*Ameiurus* spp.), yellow perch (*Perca flavescens)*, and walleye (*Stizostedion vitreum*) are also important sport fish that may be present near the landfill for prolonged periods throughout the year.

3.1.5.4 Wildlife Species

The following wildlife species that are indigenous to this area of the Columbia River Gorge are federally (USFWS) and/or state (ODFW) listed as endangered or threatened (USFWS 2009):

- Northern spotted owl *(Strix occidentalis caurina)* – Federally and state-listed threatened
- Bald eagle *(Haliaeetus leucocephalus)* – State-listed threatened

- Columbia white-tailed deer *(Odocoileus virginianus leucurus)* – Federally listed endangered

The northern spotted owl lives in old-growth forests of the nearby Mount Hood and Gifford Pinchot National Forests. No old-growth forest exists on Bradford or Cascade Islands, and it is unlikely that adult spotted owls occur there due to lack of suitable nesting habitat. However, juvenile spotted owls might pass through the area.

The bald eagle is the only special-status piscivorous species that has the potential to occur in the upland habitats of Bradford Island. Bald eagles occur as nesting and wintering residents of the Columbia River Gorge/Bonneville Dam area. Eagles primarily feed on fish, waterfowl, and waterbirds that occupy the Bonneville Dam Forebay. Several bald eagles were observed during Landfill investigations by USACE and URS personnel during 2001.

Columbia white-tailed deer are very unlikely to occur on Bradford or Cascade Islands. Habitat for this species most frequently consists of riparian zones and bottomland hardwood forests and agricultural areas, including islands within the Columbia River downstream of Portland, Oregon (between RM 32 and RM 50), approximately 100 miles downriver from Bonneville Dam.

3.1.6 Land Use and Population

3.1.6.1 Land Use

3.1.6.1.1 Project-Related Land Use

The Bonneville Project is a multiuse project, managed for hydropower, navigation, recreation, and natural resource and wildlife preservation. The Bonneville Master Plan (USACE 1997a) describes the land use details for the Project. Specific Project uses are described below.

Areas of Bradford Island are specifically managed for wildlife use. Thirteen acres of wooded and open areas on the eastern tip of Bradford Island are for multiple resource wildlife management, primarily goose nesting and pasture areas. The open area immediately south of the service building is managed for goose pasture. Geese also use lawn areas associated with the visitor's facilities for feeding. The downstream western end of the island has 34 acres used for low-density recreational fishing. Eighteen acres on Bradford Island are used for visitor facilities, and the remaining acreage is used for project operations, including office, storage, and equipment maintenance facilities.

Approximately half of Cascade Island (34 acres) is managed for goose pasture, with small areas set aside for goose nesting. The remainder of Cascade Island is used for project operations, including equipment storage and powerhouse management.

All of Goose Island is set aside for goose nesting or pasture. A portion of the north bank of the Columbia River (Washington State) between the Second Powerhouse and an upstream Tribal treaty fishing site is also goose pasture.

Hamilton Island is located two river miles downstream of the Bonneville Project and is a 221-acre multiple resource management area providing habitat for resident wildlife species. Three acres are managed specifically for goose foraging, and 27 acres are managed for low-density recreation, primarily fishing from the bank and a boat launch.

Lawn areas of Robins Island and the fish hatchery are used for goose foraging. The fish hatchery on the Oregon shore is a 22-acre cooperative use site with ODFW. The hatchery is mitigation for

resource damage caused by the dam construction. Portions of Hamilton Island also are managed for goose pasture. Fort Cascade is a 56-acre cultural resource area on the downstream Washington shore preserved because of Native American and early European American settlement. Approximately 46 acres of the north shore of the river within the Project are used for low-density recreation, and 2 acres are specifically for goose foraging.

Other visitor facilities include the Navigation Lock visitor area (6 acres) and the north shore visitor complex (22 acres). Other areas for recreation on the project include Robins Island (21 acres), the south shore area near the fish hatchery (24 acres), and the Pacific Crest Trailhead (4 acres). The remaining Project areas (more than 100 acres) are used for Project operations. There is no public access to the portion of Bradford Island involved in this RI.

There are no plans to change the above land uses at the Project, therefore these appear to be the likely future land uses.

3.1.6.1.1 Surrounding Area Land Use

The Bonneville Dam complex lands set aside specifically for project operations include 97 acres of land that is owned and operated by USACE, and occupied by the main facilities at the Project.

The dam complex is located within the Columbia River Gorge National Scenic Area. The Mount Hood National Forest is located south of the dam and south of Interstate 84. Gifford Pinchot National Forest is located on the Washington side of the river, approximately 6.5 miles north of the dam. Beacon Rock State Park is located approximately 2.5 miles to the west, on the Washington side of the river. All of these areas are used for various forms of recreational activities including fishing, boating, hiking, biking, and camping.

The vast majority of land near Bonneville Dam is dedicated to forestry activities, with agriculture a distant second. Timber resources in the region support large, integrated timber processing industries in the major population centers (WDF et al. 1990).

Pierce and Ives Islands are located downstream of the dam at RM 142. Pierce Island is a 200-acre nature conservancy preserve dedicated to protecting native riverine flora and fauna. Ives Island is part of the Gifford Pinchot National Forest and is managed by the Columbia River Gorge National Scenic Area.

Population densities along subbasin tributaries are low, and uses of the streams are not as significant as those along the Columbia River. Habitat alteration and loss due to logging or agriculture are more common threats on these small streams (WDF et al. 1990).

3.1.6.2 Population Profiles

The three distinct human populations in the general site area are the site staff, site visitors, and the nearby residents.

3.1.6.1.2 Site Staff

The USACE currently employs approximately 154 full-time-equivalent positions at the Bonneville Dam complex. Staff duties include a wide range of occupations, including maintenance, construction, office staff, visitor services, and natural resource management.

Approximately 10 additional staff from the Portland District headquarters are stationed at the dam. Approximately 300 fisheries-related personnel (contractors/researchers from state and federal agencies) work at the dam from April through September. The number of construction

and service contractors at the project varies depending on workloads but can number approximately 175 people (McCavitt, pers. comm. 2006).

3.1.6.1.3 Site Visitors

A road from Interstate 84 provides access to the Bonneville Dam complex. The access road is gated, and visitors are allowed to access several dam facilities (visitor centers, fish ladders, etc.). The site and general vicinity on Bradford Island is gated and off limits to the public. Only USACE personnel and authorized visitors are allowed into these areas.

3.1.6.1.4 Nearby Residents

No permanent residential dwellings are located on the Project. The primary population center in proximity to the dam is the town of North Bonneville, situated on the Columbia River just west of the dam on the Washington side of the river. The current population is estimated at approximately 950 persons.

Major population centers to the west include Portland, Astoria, and St. Helens in Oregon, and Vancouver, Longview-Kelso, and Camas-Washougal in Washington. The cities of Cascade Locks, Hood River, and The Dalles in Oregon and Stevenson, Carson, and White Salmon in Washington lie upstream of the dam. Municipal and industrial pollution from these urban areas are expected to have affected the water quality of the mainstem Columbia River. Population growth is anticipated to result in the conversion of forest, rural residential and agricultural land uses to high-density residential uses, with potential impacts to habitat conditions (Lower Columbia Fish Recovery Board [LCFRB] 2004).

3.1.6.3 Beneficial Uses

According to DEQ guidance for determining beneficial water uses (DEQ 1998a), groundwater may be classified as unlikely to be suitable for potable water uses if it meets the criteria of greater than 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS) and yield less than 0.5 gallons per minute (720 gallons per day). Neither the shallow perched groundwater nor the deeper groundwater at Bradford Island appears to meet the yield criterion. A water supply well originally drilled at Bradford Island to supply potable water to on-site workers was left inactive due to inadequate yield (McCavitt, pers. comm. 2001). The well was formally abandoned in 2008. Therefore, potable water supply use is a highly unlikely potential beneficial use for groundwater.

Designated beneficial uses for surface water in the mainstem of the Columbia River are described in Oregon Administrative Rules (OAR) 340-41-0101 (DEQ 2009a). They include a variety of high-quality uses such as public and private domestic water supply, fishing, water contact recreation and protection of fish and aquatic life (Table 3-3). Beneficial use designations for fish uses include salmon and steelhead migration corridors as well as shad and sturgeon spawning and rearing (Table 3-4).

3.2 Site History

Construction of the First Powerhouse and navigation lock, spillway, fish passage facilities, fish hatchery, and office and maintenance buildings began in 1933. Operations at the Bonneville Dam complex began in 1938. During World War II, in addition to enlarging the first powerhouse and installing additional generators, the military installed anti-aircraft batteries and a rifle/pistol range near the present day location of the service center (USACE 2005).

Between 1974 and 1981, the Second Powerhouse was constructed adjacent to the Washington State shore, to aid in supplying the electrical power needs of the Northwest. The construction of the Second Powerhouse required the relocation of the former town site of North Bonneville, which was relocated approximately 1.5 miles downstream, 4 miles of Washington Highway 14, and 3 miles of Burlington Northern railroad track. During the roadway/railway construction activities, a significant archeological site was excavated. First noted in the Lewis and Clark journals, the site is the only known relatively undisturbed archeological site along the lower Columbia River and provided evidence of 500 years of occupation from the time of Native American occupation to the time of historic settlement in the mid-1800s. This site is on the National Register of Historic Places. Retrieval of cultural material necessary for site interpretation began when it was realized that construction activities would affect the archeological site. Retrieval of cultural material was completed in the summer of 1979 (USACE 2005).

A second navigation lock was constructed at the Bonneville Power Complex on the Oregon side between 1989 and 1993. Associated with construction of the new lock, the southeastern edge of Bradford Island was excavated to improve the approach channel. Soils from that excavation were placed to create Goose Island, 0.5 mile upstream near the Oregon shore.

3.3 Current Facility Operations

The USACE operates and maintains Bonneville Lock and Dam for hydropower, fish and wildlife protection, recreation, and navigation. The major features of the dam complex include a spillway, two powerhouses, two navigation locks, and a fish hatchery. The fish hatchery, main office, and navigation lock visitor center are located on the Oregon shore of the Columbia River. A warehouse and garage facility and navigation lock support facilities are located on Robins Island. The major features on Bradford Island include the Bradford Island visitor center, fish ladders, the service center building, the equipment building, and the former sandblast building. A fish ladder is located on Cascade Island, and the Washington Shore visitor center is located on the north shore of the Columbia River.

3.4 Bonneville Project Regulatory History

The Bonneville Lock and Dam was initially placed on the Federal Facilities Compliance Docket after the 1986 explosive failure of a bushing on an oil circuit breaker in the switchyard on the roof of the First Powerhouse. The bushing failure released approximately one pound of PCBs in tar from the core of the bushing. The bulk of the tar fell on the powerhouse roof, but an unknown quantity reached the river. A second bushing failed in 1991 with similar results. Both spills were cleaned up in accordance with the Toxic Substances Control Act (TSCA) and documented in a preliminary assessment (PA) in 1992. In 1994, the USEPA declared No Further Action (NFA) was necessary with respect to these accidental releases. All PCB-containing bushings and circuit breakers on the powerhouse roof were replaced in the 1995 rehabilitation of the powerhouse.

In 1987, Hamilton Island, a former construction landfill on project lands 1.5 miles downstream from the Second Powerhouse in Washington State, was placed on the Federal Facilities Compliance Docket. The site was investigated for wastes from the construction of the Second Powerhouse at Bonneville Dam, possible PCB waste from the Bonneville project, and wastes from the demolition of the town of North Bonneville. In 1991 the site was placed on the National

Priorities List (NPL) under CERCLA. USACE completed a RI/FS in 1994 and the site was delisted by USEPA in 1995 after a NFA ROD.

USACE maintains a point source discharge permit for discharges from the facility's wastewater treatment plant. The plant services all sanitary waste facilities on the project. The ODFW-managed fish hatchery discharges are not treated by this facility but have a separate discharge in Tanner Creek.

The investigation around Bradford Island began as part of the evaluation of the former Bradford Island Landfill. The Landfill is a former waste disposal site at the Bonneville Lock and Dam Project on the Oregon side of the river. The Landfill was used from the early 1940s until the early 1980s. On June 13, 1996, the USACE submitted a letter to USEPA Region 10 and DEQ, informing them of the presence of the Bradford Island Landfill. In response to the letter, the USEPA requested that sediment samples be collected in the Columbia River around the Landfill perimeter, and that groundwater seep samples be collected if seeps were identified. These issues were considered during the first investigation (the 1998 SI) at the site.

The Bradford Island Landfill was added to the DEQ ECSI database on April 1, 1997. On April 24, 1997, the Bonneville Lock and Dam Project signed a Letter of Intent to participate in DEQ's VCP for the investigation and remediation of the Landfill site. On February 18, 1998, the Portland District Engineer signed a DEQ Voluntary Cleanup Agreement letter for the Landfill site. In 2004, USACE elected to continue the Bradford Island project under the CERCLA.

The USACE will complete the RI/FS in accordance with CERCLA principles, with DEQ requirements as applicable, or with relevant and appropriate requirements (ARARs). Both USEPA and Ecology have been provided the opportunity to comment and participate in the USACE investigations. Neither of these two agencies have committed resources to the project, but support the USACE efforts and have informally deferred to DEQ. The USACE is currently working with the DEQ to address the state's concerns regarding this investigation and any associated cleanup activities.

3.5 Investigation Operable Units

The investigations on Bradford Island began as part of the evaluation of the Landfill, which was used from the early 1940s to the early 1980s. In the course of numerous investigations, it became apparent that past upland and in-water disposal, as well as other operational activities, had resulted in contamination of the site soil and groundwater, as well as the sediments of the adjacent river.

The areas requiring additional evaluation and possible response actions were divided into the Upland OU and the River OU (Figure 1-3). The Upland OU includes four separate AOPCs (Figure 1-4):

- Landfill AOPC
- Sandblast Area AOPC
- Pistol Range AOPC
- Bulb Slope AOPC

Sections 5.0 and 6.0 detail the historical and recent investigations that have been conducted at the Upland and River OUs. The following presents a brief description of the each of the Upland OU AOPCs and of the River OU.

3.5.1 Upland OU

3.5.1.1 Landfill AOPC

Historical investigations at the Landfill AOPC began in 1998. In general, the investigations found that for approximately 40 years, the USACE managed, stored and disposed of waste materials at the landfill in excavated pits or existing depressions on the eastern end of Bradford Island (Figure 1-4). Some additional wastes were disposed of over the northern and eastern edges of the island. Pesticide/herbicide mixing and rinsing of pesticide/herbicide application equipment also occurred near the Landfill, Figure 3-3. The Landfill AOPC boundary shown on this Figure was defined based on known historical use at the site, physical parameters (e.g., the river), and site observations and investigations, including geophysical surveys of the Landfill.

Landfill Waste Characterization and Extent

On February 24, 1997, the Portland District USACE performed a review of available historical aerial photographs of the Landfill AOPC between the years 1936 and 1982. Information derived from the aerial photograph review indicated that use of the Landfill began around 1942, and by 1952, the Landfill appeared to be in its heaviest use. The photographs indicated that deposition of trash occurred intermittently until the early 1980s, and materials and equipment stored in the Landfill AOPC included drums, aboveground storage tanks, vehicles, lumber, and scrap metal. By 1982, the surface of the Landfill AOPC had been capped with soil cover. Neither the overall geographic extent, the estimated depth of landfilled materials, nor the volume of materials disposed within the Landfill could be determined from the review of the aerial photographs (URS 2000).

Based on information from site investigations including electrical resistivity data, seismic refraction data, and boring logs, the volume of landfilled material was estimated to be between 7,500 cubic yards (cy) and 9,900 cy, with a maximum depth of 15-feet below ground surface (bgs). The waste was buried in separate pits, rather than one continuous pit. Waste either observed onsite or known to have been disposed of in the Landfill includes: household waste, project-related wastes (grease, light bulbs, sandblast grit), electrical debris, up to 50 ballasts, broken glass, rubber tires, metal debris, wood debris, metal cables, asbestos containing building materials, burned debris, ceramic insulators, and mercury vapor lamps. Some exposed wastes have been observed on the northern edge and the surface of the Landfill itself, including concrete rubble, steel cables, a few empty buckets and drums, plastic planter buckets, empty cans and paint solids, and metallic slag and partially-burned construction debris, and miscellaneous trash items (Tetra Tech 1998, URS 2004a). PCB-containing light ballasts were discovered in the river north of the Landfill AOPC in March 2000 and March 2001 (see Section 3.5.2).

Landfill Management and Assessment

The Bradford Island Landfill and the equipment storage area in the vicinity of the Landfill AOPC are no longer in use by the Bonneville Dam operation. In 1989, approximately 8-inches of additional soil cover was placed on the Landfill site by the USACE (Hibbs, personnel comm. 2001). Although this portion of Bradford Island is managed as wildlife for geese according to the

Bonneville Master Plan (USACE, 1997a), active management (periodic mowing) of the habitat ceased in the middle to late 1990s to prevent geese from laying eggs in areas that are under investigation (Hibbs, personnel comm. 2001).

The Bradford Island Landfill was added to the DEQ ECSI database on April 1, 1997. On April 24, 1997, the Bonneville Lock and Dam Project signed a Letter of Intent to participate in DEQ's VCP for the investigation and remediation of the landfill site. On November 6, 1997, the Bonneville Lock and Dam PM signed a DEQ Voluntary Cleanup Agreement letter for the landfill site. The USACE started an engineering evaluation/cost analysis (EE/CA) in 2005 to assess the value of conducting a non-time critical removal action at the Landfill AOPC. The Landfill EE/CA work was suspended pending completion of this RI/FS.

Overall, disposal and handling practices in the vicinity of the Landfill AOPC have impacted soil and groundwater with low levels of petroleum products, metals, PCBs, pesticides, and herbicides. Disposal of materials in the Columbia River have impacted near shore sediments with petroleum products, metals, and PCBs (addressed in the River OU). Debris disposed of in the river have been removed.

No evidence of runoff or erosion was observed or predicted through modeling for the Landfill surface (URS 2009f). Minor runoff was observed on the Landfill access road. The source of the Landfill road runoff was a groundwater seep at the base of the steep slope along the southern margin of the Landfill. The water flows west along the road and then infiltrates along the northern margin of the road to the west of the Landfill. The runoff water was clear at the time of the field survey, indicating that the flow of seep water along the road is not causing soil erosion. Runoff from the road appeared to infiltrate and evidence of direct discharge of road runoff to the river was not observed (URS 2009f).

While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, undercutting was observed along the waterline at the north slope indicating that historical mass wasting likely occurred. Although the potential for bedrock failure is low, if mass wasting were to occur on the steep slopes, the soils may reach the river.

3.5.1.2 Sandblast Area AOPC

The Sandblast Area AOPC includes the area surrounding the former sandblast building on the eastern end of the site (Figure 1-4). The Sandblast Area AOPC consists of the following subareas that are associated with different sources of contamination (Figure 3-4):

- Former disposal area for spent sandblast blast grit
- Former transformer maintenance area east of the former sandblast building
- Former Hazardous Material Storage Area (HMSA) located east of the equipment building
- An inferred release of tetrachloroethylene (PCE) from an aboveground storage tank (AST) historically located in the vicinity of the current HMSA
- Laydown area used for current storage of industrial equipment and materials located along the north and south sides of the landfill access road

The Sandblast Area AOPC boundary, shown on Figure 3-4, was defined based on known historical use at the site, physical parameters, and site observations and investigations.

Within the Sandblast Area AOPC, a portion of the stormwater runoff from impervious surfaces (asphalt) drains to four catch basins (designated #1, #2, #3, and #4 in this report) that discharge

to the Columbia River through two outfalls. In October 2001, the USACE cleaned the sediment from the stormwater system, and replaced the filter fabric socks that line each catch basin (URS 2002e). USACE Bonneville Dam project employees replace the socks on a periodic basis.

It appears, however, that the majority of the runoff from asphalt immediately southeast of the former sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. Eroded soil from the rills combined with sandblast grit from further upslope has been observed accumulated at the base of the slope and behind one of two concrete curbs that run along the base of the slope at the equipment laydown area (URS 2009f).

In 2009, evidence of runoff was observed along the Landfill access road and the adjacent equipment laydown area. These areas are flat and evidence of erosion is generally lacking. Runoff from the road appears to flow north onto a vegetated area between the road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates before reaching the river (URS 2009f). Within the remainder of the Sandblast Area AOPC, in particular vegetated areas, no evidence of surface runoff, soil erosion, or sediment deposition was observed.

Former Sandblast Building and Sandblast Grit Disposal Area

A variety of equipment associated with the Bonneville Dam complex has historically been painted with materials that contained metallic (including lead and zinc chromate systems) and organometallic compounds. This equipment was periodically stripped with blast material and repainted in the former sandblast building. The former sandblast building was used for sandblasting operations and painting from approximately 1958 to 1988. After 1988, the sandblasting and painting operations moved to the service center building. No records of disposal activities for sandblast grit were kept from 1958 to 1994. Application of lead-based paints has reportedly not occurred at the dam complex since the early 1980s. A record of disposal from 1994 shows 215,680 pounds of sandblast grit were disposed of as Resource Conservation and Recovery Act (RCRA) hazardous waste, and after 1997 waste disposal records indicate that on average, approximately 70 tons of spent blast media were generated per year from sandblasting operations (URS 2006a).

Based on the presence of sandblast grit adjacent to the former sandblast building (Figure 3-4), spent sandblast grit was historically spread onsite for an unknown period prior to 1994. Previous investigations concluded that the primary source of soil contamination in the Sandblast Area is from the open disposal of sandblast grit (URS 2006a). The disposal of spent sandblast grit in the area immediately east of the former sandblast building has resulted in the release of metallic and organometallic constituents, which were used in historical painting operations, into the surface and subsurface soil. This material has subsequently been transported across the site by surface water runoff into the stormwater drainage features (Figure 3-4).

Former Sandblast Building Septic System

A septic system formerly serviced a bathroom located in the painting (western) portion of the former sandblast building. Floor drains in the former sandblast building may have also discharged into the septic system. The system reportedly includes a tank and drain field. The septic tank and the drain field are located near the north-central side of the former sandblast building (Figure 3-4). The system is not currently in use (the sandblast building recently

demolished). Because a septic tank located on Robbins Island had been backfilled with sandblast grit, the former sandblast building septic tank was investigated to determine if it had been similarly backfilled with sandblast grit. Investigation of the septic tank determined that it had not been backfilled with sandblast grit and was not a source of contamination at the Sandblast Area AOPC (URS 2006a).

The remnants of a small (estimated at less than 100 square feet) burn pit was located at the eastern end of the sandblast disposal area (URS 2006a). The former burn pit is bermed with wood timbers and earthen materials, and the pit contains approximately 2 cy of solid waste consisting of charred wood (mostly), electrical wire, scrap metal, small electrical components, and broken glass. The burn pit is no longer used and the last date of use is not known. Based on analytical data, the burn pit itself does not appear to be a source of contamination. Instead, the sandblast grit located across the sandblast disposal area, including the burn pit, appears to be the source of contamination.

Transformer Disassembly Area

In 1995, PCB-containing transformers were disassembled by the USACE at the paved parking area on the east side of the former sandblast building. On November 22, 1995, approximately 1 quart of PCB-containing oil was released. The release was spread northward by stormwater runoff and into the stormwater drainage system (previously described), which has two outfalls to the river. At the time of the release, a sheen of oil was observed on the Columbia River below the outfall. The release was contained using booms and absorbent pads placed on the upland areas of the release and below the storm drain outfall in the river. At the time of the release, samples were not collected from the stormwater system. Figure 3-4 depicts the transformer disassembly area and the storm drain system.

Former Hazardous Material Storage Area

Prior to 1993/1994, hazardous waste generated at the Bonneville Dam complex was stored at the former HMSA (Figure 3-4). The former HMSA was located approximately 200 feet to the south of the former sandblast building and is sometimes also referred to as the 'former drum storage area.' The former HMSA pad was constructed of wood and metal and did not have a secondary containment system or berms (URS 2002c). Based on investigations in the vicinity of the former HMSA, there have been limited releases of contaminants.

AST Release in the Vicinity of the Current HMSA

Since approximately 1993 or 1994, hazardous waste is stored at the current HMSA, located 50 feet southeast of the former sandblast building (Figure 3-4). The current HMSA was constructed in 1993 or 1994 and consists of a 2,300 square feet (51.5 feet long by 45 feet wide) concrete pad with berms that is partially covered with a steel-framed canopy. A 75 to 100 square foot enclosed flammable materials storage shed is located on the western edge of the storage pad. The excavation for the concrete pad foundation was approximately 2 feet deep (over an area of 51.5 feet long by 45 feet wide), meaning 150 to 200 cy were excavated for the construction. The excavated material was transported to the Bradford Island Landfill for disposal. No record of the type of material (e.g., percent of sandblast grit) that was excavated is available (URS 2006a). The current HMSA does not appear to be a source of contamination.

Prior to the construction of the current HMSA, an approximately 300-gallon AST was formerly located the vicinity. Waste paints were temporarily stored in this AST until the late 1990s at

which time the tank was removed. The tank and the waste within it were appropriately disposed of offsite. During an investigation, a solvent odor was noted in a soil sample collected adjacent to the current HMSA (URS 2002c). Analytical chemistry results for the soil sample identified the presence of several VOCs. From these results, it has been inferred that there was a historical release from the AST formerly located in the vicinity of the current HMSA.

Equipment Laydown Area

The USACE stores industrial equipment and materials along the northern and southern portions of the Landfill access road (Figure 3-4). Periodic grading of the laydown area has been performed to expand storage capacity. Soils may have become contaminated with oil, metallic debris, or other contaminants due to this equipment storage.

3.5.1.3 Pistol Range AOPC

The Pistol Range AOPC is located on the south side of Bradford Island (Figure 1-4). The pistol range was used for small arms target practice from sometime between the early 1940s and the late 1950s to the late 1960s or early 1970s. No other land use associated with the pistol range is known. The pistol range consisted of an approximately 20-foot by 20-foot firing shed and a 30-foot long, 7-foot tall heavy timber backstop constructed of treated lumber. The firing shed, located 80 feet southwest of the backstop, fell into disrepair and was knocked down in the 1990s by the USACE. The building materials from wood-framed and wood-sided structure were not removed following demolition. Due to the historical land use of the Pistol Range AOPC, the soils immediately adjacent to the firing shed, backstop, and areas down gradient of the shed and backstop have been impacted with metals associated with firing range activities.

The overall slope of the Pistol Range AOPC is to the southeast toward the Columbia River. The topography of the area consists of a series of cuts and fills, resulting in a sequence of slopes and flat areas. Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation and does not show evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. When the Pistol Range AOPC was in use as a firing range the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River.

3.5.1.4 Bulb Slope AOPC

The Bulb Slope AOPC was identified during the removal of equipment offshore of Bradford Island in February and March of 2002. The Bulb Slope AOPC is a fan-shaped accumulation of glass and electrical light bulb debris that extends across approximately 1,900 square feet of a steep slope between the Columbia River and the Landfill access road (Figure 1-4). The vegetated disposal area slopes steeply from the Landfill access road (approximate elevation of 95 to 100 feet above msl) down to the Columbia River (approximate elevation of 75 feet msl; University of Washington 2003). The slope angle is near vertical at the base of the slope for a height of approximately 4 feet above the river level. The normal operating range for the Bonneville pool is between 71.5 feet msl elevation and 76.6 feet msl as measured at the dam (USACE 1998). Based on this information, the base of the bulb slope may be partially submerged during some periods.

The debris is concentrated in the center of the slope and the types of glass observed included internal/external light bulbs, fluorescent light bulbs, automobile light bulbs, 1- to 1.5-inch-diameter glass tubes, clear window pane glass, white-colored molded glass (possibly lamppost

light covers), and miscellaneous glass beverage containers. Based on the analytical results of soil sampling collected in 2002, surface soils at the Bulb Slope AOPC are impacted with metals (lead and mercury), PCBs, and total petroleum hydrocarbons (TPH).

The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface runoff or overland flow to the river. At the base of the slope, however, wave erosion has resulted in mass wasting (small slope failures) of material into the river. Mass wasting appears to be the only potential mechanism for transport of debris and/or contaminated soil into the river.

3.5.2 River OU

Historically, electrical equipment debris was disposed of directly in the River on the north side of the Landfill AOPC. Figure 3-5 depicts the in-water historical source locations, identified as Former Debris Piles (#1 through #3). The electrical equipment debris included light ballasts, electrical insulators, lightning arresters, electrical switches, rocker switches, a breaker box, and electrical capacitors. The electrical debris contaminated the surrounding sediment with PCBs, PAHs, and metals. The electrical equipment debris were removed in 2000 and 2002 (Appendix E of URS 2002a,b) and the majority of the associated PCB-contaminated sediment was removed in 2007 (HAI 2007). Residual contamination in the sediment includes PCBs, PAHs, and selected metals.

4.0 CONCEPTUAL SITE MODEL

The purpose of this conceptual site model (CSM) is to identify the physical setting and potential sources of contamination, including their transport media and release pathways. The CSM was developed with information gathered from historical investigations and recent investigations (see Sections 5.0 and 6.0). Because the CSM is 'conceptual', it is not dependent on the quantification of the chemical nature and extent and fate and transport.

The site consists of two OUs: the Upland OU and River OU (Figure 1-3). The potential sources of contamination for each of these units are discussed in the following sections. The conceptual exposure models (CEMs), included in Sections 11.0 and 12.0, determine which receptor exposure pathways are complete, potentially complete and incomplete.

4.1 Upland Operable Unit

The physical setting and potential or known sources of contamination in the Upland OU (Figure 1-4) are summarized in this section. Appendix C includes photographs showing each of these AOPCs. Sections 5.0 and 6.0 provide the historical and recent investigation information from which Site sources were identified.

4.1.1 Physical Setting

Physical characteristics of Bradford Island, which are relevant to the discussion of site transport mechanisms, are summarized below.

- There are two areas of higher elevation in the center of the island that range from 170 feet to 195 feet above msl. For reference, the Landfill AOPC is at elevation 120, the Sandblast Area AOPC is at elevation 98, and the Pistol Range AOPC is at elevation 94 feet above msl.
- River stage elevation upstream of the dam at the island averages approximately 74 feet above msl.
- North of the Landfill AOPC, the land surface drops steeply by approximately 30 to 35 feet to the Columbia River. The topography east of the Landfill AOPC also drops steeply to the Columbia River. West of the Landfill AOPC, the topography slopes gently to the west. Topography in the Sandblast Area AOPC slopes to the north with areas of varying steepness. The riverbank is a rip-rapped north of the Sandblast Area AOPC. The Bulb Slope AOPC is situated entirely on the steeply sloping north edge of the island. The land rises moderately south of the Landfill, Sandblast Area, and Bulb Slope AOPCs, and southwest of the Landfill AOPC. The Pistol Range AOPC consists of a pair of vegetated topographic benches stepping down toward the Columbia River to the South. The shoreline is very gently sloped into the adjacent lagoon.
- Bedrock outcrops of conglomerate, sandstone, and limited siltstone are exposed along the north slope of the island. The potential for bedrock failure is low.
- Surface water drainage generally follows sloping topography as sheet flow, before infiltrating into the porous soils, particularly in vegetated areas.
- Precipitation that infiltrates the soil at the island may percolate to groundwater. Under both wet season and dry season conditions, shallow groundwater at the island likely flows to the

north on the north half of the island and to the south on the south half of the island. Groundwater discharge to surface water occurs as diffuse flow in the high permeability materials in the steep slopes on the northern edge of the island as well as in seeps located in vertical fractures in the underlying low-permeability materials. Groundwater may enter the river through bottom sediments or above-water surface seeps.

4.1.2 Landfill AOPC

The primary sources of COIs released at the Landfill AOPC are trash pits, Landfill mixed-waste disposal areas, and the pesticide mixing area. Based on information from previous site investigations including electrical resistivity data, seismic refraction data, and boring logs, the Landfill volume is estimated to be between 7,500 cy and 9,900 cy, with a maximum depth of 15-feet bgs (Tetra Tech 1998, URS 2004a). The waste was buried in separate pits within the Landfill, rather than one large pit. Pesticide/herbicide mixing and rinsing activities historically occurred just south of the Landfill. Stained soils have been observed in the center of the Landfill AOPC (potentially indicating a historical burn area).

COIs have been released from these primary sources into the soil and groundwater (secondary sources). During wet portions of the year, the groundwater elevation can potential rise high enough to encounter waste materials in a small portion of the Landfill AOPC. Analytical data demonstrate that soils and/or groundwater are impacted by metals, herbicides, pesticides, PCBs, VOCs, SVOCs (including PAHs), and/or TPH. While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, undercutting was observed along the waterline at the north slope indicating that historical mass wasting likely occurred. Although the potential for bedrock failure is low, if mass wasting were to occur on the steep slopes, the soils may reach the river.

4.1.3 Sandblast Area AOPC

The Sandblast Area AOPC includes the area surrounding the former sandblast building on the eastern end of the site (Figure 3-4). The Sandblast Area AOPC consists of the following subareas that are associated with different sources of contamination:

- The former disposal area for spent sandblast blast grit, which resulted in the release of metals and potentially butyltins into the soil (secondary source) and to the river via the stormwater drainage system.
- The former HMSA located east of the equipment building, which has potentially resulted in limited soil contamination of metals, pesticides, and PAHs.
- The paved former transformer maintenance area east of the former sandblast building, at which approximately 1 quart of PCB-containing oil was released on November 22, 1995, and which may have been transported to adjacent soils (secondary source) and possibly the river via the stormwater drainage system.
- An inferred release from an AST historically located in the vicinity of the current HMSA, which resulted in the contamination of soil, and subsequently groundwater, with VOCs.
- The equipment laydown area used for historical and current storage of industrial equipment and materials located along the north and south sides of the Landfill access road, which appears to have resulted in the contamination of soil with metals, pesticides, PCBs, and SVOCs (including PAHs).

Contaminants have been released from these primary sources (i.e., sandblast grit, PCB-containing oil, hazardous material storage, and equipment storage) to soil and/or groundwater (secondary sources). In addition, during a site visit in 2009 an area northeast of the former sandblast building was observed to have been recently disturbed and was identified as erodible, whereby contaminated surface soil is transported to the river via stormwater drainage and surface water runoff (URS 2009f). During the past year, this area has become revegetated (see the photo in Appendix C) and the soils are no longer considered erodible.

4.1.4 Pistol Range AOPC

The Pistol Range AOPC is located approximately 75 feet southeast of the equipment building and north of the Columbia River (Figure 1-4). The pistol range was used for small arms target practice from sometime between the early 1940s and the late 1950s to the late 1960s or early 1970s. No other land use associated with the Pistol Range AOPC is known. As a result of the historical land use of the Pistol Range AOPC, the soils immediately adjacent to the firing shed, backstop, and areas down gradient of the shed and backstop are impacted with selected metals associated with firing range activities.

Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation and does not show evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. When the Pistol Range AOPC was in use as a firing range the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River (e.g., the adjacent lagoon).

4.1.5 Bulb Slope AOPC

The Bulb Slope AOPC is a fan-shaped accumulation of glass and electrical light bulb debris that extends across approximately 1,900 square feet of a steep slope between the Columbia River and the Landfill access road (Figure 1-2). The Bulb Slope AOPC surface soil is impacted with metals (lead and mercury), PCBs, and TPH from the discarded light bulbs.

The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface runoff or overland flow to the river. At the base of the slope, however, wave erosion has resulted in mass wasting (small slope failures) of material into the river. Mass wasting appears to be the only potential mechanism for transport of debris and/or contaminated soil into the river.

4.2 River Operable Unit

The physical setting and potential or known sources of contamination in the River OU are summarized in this section. Sections 5.0 and 6.0 provide the historical and recent investigation information from which Site sources were identified. Sources of contamination from both in-water placement of debris and overland transport from the Upland OU have likely impacted sediments and surface water in the River OU.

4.2.1 Physical Setting

Physical characteristics of the River OU, which are relevant to the discussion of site transport and exposure mechanisms, are summarized below.

- The average annual variation of water level within the River OU is 3 to 5 ft. River stage elevation of the River OU at the island averages approximately 74 feet above msl.
- Based on historic photographs and USACE hydroacoustic sounding data, a submerged shelf appears to be adjacent to the north side of Bradford Island at a depth of about 30 ft below pool level. This shelf appears to be about 50 ft wide, parallel to the north shore of the island. Shallow water (20 ft deep or less) also occupies a band approximately 50 ft wide along the south shoreline of Bradford Island.
- Hydraulic modeling of the waters near Bradford Island was conducted by the USACE (Langsley 1999). This modeling indicates that a large eddy forms behind the dam and creates a reverse current flow next to Bradford Island. This reverse flow appears to attract adult slamonoids exiting the fish ladder on their way upstream and results in the fish being swept back over the dam (Langsley 1999). Introduced fish species may be present in the River OU for prolonged periods through the year and are popular recreational species with a recognized societal value.

4.2.2 Sources of Contamination

Historically, electrical equipment debris was disposed of directly in the River on the north side of the Landfill AOPC. Figure 3-5 depicts the in-water historical source locations, identified as Former Debris Piles (#1 through #3). The electrical equipment debris included light ballasts, electrical insulators, lightning arresters, electrical switches, rocker switches, a breaker box, and electrical capacitors. The electrical debris contaminated the surrounding sediment with PCBs, PAHs, and metals. The electrical equipment debris were removed in 2000 and 2002 (Appendix E of URS 2002a,b) and the majority of the associated PCB-contaminated sediment was removed in 2007 (HAI 2007). Residual contaminated sediment, as well as historically contaminated biota (e.g., fish and shellfish) may currently be sources of contamination.

In addition, the Upland OU sources identified in Section 4.1 may also be sources of contamination for the River OU through overland transport (Figure 4-1) or groundwater discharge to the river.

4.3 Release Mechanisms and Transport Media

Given the physical characteristics of the site and the current potential sources described above, the following mechanisms may transport site contaminants from one or more of the AOPCs to others areas within the Upland OU and/or to the River OU:

1. Volatilization of contaminants in soil to air, or dust generation and release of contaminants in particulate form to air.
2. Leaching and infiltration of contaminants from buried debris and/or contaminated soil to groundwater.
3. Discharge of contaminants in the perched groundwater zone to surface water (via seeps).
4. Overland transport of spent sandblast grit and surface water runoff of contaminants in soil directly to River surface water or via the stormwater drainage system outfalls.
5. Transport of contaminants via soil erosion and/or mass wasting to surface water.

In addition, the following mechanisms may redistribute site contaminants within the River OU:

6. Sorption/dissolution of surface water contaminants to/from sediments.
7. Contaminated sediment transport within the river.
8. Potential surface water communication to the deeper groundwater zone.

The CSM (Figure 4-2) depicts these current release mechanisms and transport media. Due to the potential surface water communication with the deeper groundwater zone, contaminants in the River OU may be transported into the deeper groundwater zone. However, there are no receptors that would be exposed to this deeper groundwater and, therefore, this pathway is not investigated or evaluated further.

5.0 HISTORICAL SITE INVESTIGATIONS

This section summarizes investigations that occurred prior to the September 2007 RI/FS MP (URS 2007a). The results of investigations that were conducted following the RI/FS MP are summarized in Section 6.0

Except where data quality does not meet the standards outlined in the RI/FS MP (URS 2007a), analytical results from investigations in the Upland OU from 1999 to 2009 are included in the RI data set and were evaluated in the risk assessments (exceptions are noted). The relatively static physical environment of the Upland OU means that environmental data collected over the past decade can be considered representative of current conditions. Therefore, all historical Upland OU investigations are summarized, in chronological order, based on the date in which the investigations were conducted. Data are provided in Tables in this Chapter. Historical Upland OU data not utilized in the RI due to poor data quality are provided in Appendix G.

In contrast to the Upland OU, the physical environment of the River OU is much more dynamic. As discussed previously, the electrical equipment and debris and the majority of the contaminated sediment have been removed from the river. Water movement and human activities have redistributed sediment within the Forebay. Additionally, the sampling methods used to collect the historical data in the River OU are not comparable to the recent sampling which was conducted in accordance with the procedures outlined in the River OU QAPP (URS 2007b), Revised Sculpin Analysis Strategy Technical Memorandum (URS 2009b), and In Water QAPP Addendum (URS 2009c).

In order to focus on the current river conditions, only analytical results from investigations in the River OU after 2007, with the exception of smallmouth bass collected in 2006, are included in the RI data set and used in the risk assessments. Therefore, only a brief review of the historical investigations are presented in this report. A detailed summary of the historical investigations for the River OU is presented in the RI/FS MP (URS 2007a). Appendix G provides the historical River OU data not utilized in the RI.

5.1 Data Processing

The analytical data presented in this Section, as well as in the following Section (Section 6.0), was processed for use in this RI Report in a manner similar to the Upland and River DSRs (URS 2009d,e). Both processed and unprocessed data are provided in Appendix A. The following sections summarize the processing treatments for the Upland OU and River OU data necessary for utilization. A complete enumeration of the processing treatments for the data is provided in the metadata file in Appendix A. Appendix E provides the laboratory reports and Appendix F provides the data validation reports. Appendix H presents the results of the individual congener analyses, along with the methodology used for summing total PCBs as congeners, total PCBs as Aroclors, and total PAH, and tables with the sums for each sample.

- **Method Detection Limits (MDLs) and Method Reporting Limits (MRLs) –** There are both MDLs and MRLs associated with the majority of data. For some historical data, only MRLs were available, in which cases the MRLs were used in lieu of MDLs. MDLs and MRLs are presented in Appendix A. For simplicity, only the MDLs are shown in the data tables presented in this section (Tables 5-1 through 5-7) and in the tables presented in Section 6.0 (Tables 6-2 through 6-14).

- **Field Duplicates –** Results from field duplicates were averaged with corresponding primary sample values to create a single value, as long as the analytes was detected in both the primary and field duplicate samples. When averaging, the lower of the MDLs and the higher of the MRLs were assigned to the average. If the analyte was detected in only one of the pair, the detection result was used and the MDL/MRL associated with this detection was considered as the MDL/MRL of the result. If the analyte was undetected in both samples, the lowest MDL/MRL of the pair was used. This procedure follows DEQ's guidance for the treatment of data for primary samples and duplicates (DEQ 2009b).
- **Analyses –** Data from Synthetic Precipitation Leaching Procedure (SPLP), Toxicity Characteristic Leaching Procedure (TCLP), and NWTPH-HCID analyses were not included in this RI data set. The SPLP and TCLP analyses measures COI concentrations in simulated leachate from a soils sample, and are used to evaluate waste handling and disposal requirements. The NWTPH-HCID analysis is a screening analysis documenting the presence of hydrocarbons which is typically followed by quantitative analysis of specific COIs. Neither of these types of data are relevant to the RI, although all results are retained in the project database.
- **Summing PCB Congeners –** Total PCBs as Congeners were summed for each River OU media in which it was analyzed. Data qualified as "U" are undetected results at the laboratory-provided reported detection limit (RDL). Neither MDLs nor MRLs were provided by the laboratory. Data qualified as "EMPC" represent the estimated maximum potential concentration of analytes that were not definitively identified. Total PCBs as Congeners were summed using the Kaplan-Meir (K-M) method with Efron's bias correction, capped at the simple sum (see Appendix H, Tables H-7 through H-12). Undetected results were censored at the RDL; EMPC-qualified data were censored at the full reported value.
- **Summing PCB Aroclors –** Total PCBs as Aroclors were summed for each media. Since no more than two Aroclors were detected in a given medium, the K-M method could not be used to sum total PCBs as Aroclors. Instead, for summing total PCBs as Aroclors, the replacement value for individual Aroclors depended on whether or not that particular Aroclor had been detected in any of the other samples from the same media. If the analyte was undetected in all samples, a value of zero was used. If the Aroclor was detected in at least one sample in the media, the total was summed twice, once using the full MDL and once using the full MRL for censoring undetected values (see Appendix H, Tables H-4 through H-6 and Tables H-13 through H-17).
- **Summing PAHs –** In soil samples, total high molecular weight PAHs (HPAHs) and total low molecular weight PAHs (LPAHs) were summed for use in the ERAs. Total HPAHs, Total LPAHs, and Total PAHs were summed in sediment samples, for use in the ERA. HPAHs include benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene. LPAHs include 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorine, naphthalene, and phenanthrene. Total HPAHs, Total LPAHs, and Total PAHs were summed using the K-M method with Efron's bias correction, capped at the simple sum (see Appendix H, Tables H-1 through H-3 and Tables H-18 through H-22). Total LPAHs, HPAHs, and

PAHs were summed twice, once using the full MDLs and once using the full MRLs for censoring undetected values.

5.1.1 Treatment of Data from Excavations in the Upland OU

Analytical data from composite samples of excavated soils that were replaced in test pits in the Upland OU were treated as follows:

- **Sandblast AOPC Data –** Soil samples from locations "TRA-04" and "TRA-02" (sampled in 2001) were in an area where vegetation was removed by USACE in 2004. Only vegetation and soils clinging to roots were removed from site (other soils were graded and remained on site, less than 6" of soil was disturbed). Since the soils that these samples represent were not definitively removed, these analytical results were utilized in the RI Report.
- **Landfill AOPC Test Pit Data –** In 2001, six composite soil samples, initially identified as "IDW," were collected and analyzed from the soil removed from the gully test pit (BIL01TPG, BIL02TPG, BIL03TPG, and BIL05TPG) and the mercury vapor-lamp test pit (BIL28TPM and BIL29TPM). The stockpiled soils were then used to backfill their respective excavation pits. The soil may have been placed anywhere within the 0-10 feet bgs depth of the test pits. This represents an element of uncertainty when using this data, since the risk assessment process considers three potential exposure intervals (0-1 foot bgs, 0-3 feet bgs, and 0-10 feet bgs). This uncertainty was recognized in the RI/FS MP (URS 2007a) and eight additional surface and shallow soil samples were collected from the gully test pit area in 2009 as part of the Landfill data gap sampling and analyzed for select analytes. Data from these recent samples supersedes the historical data for the 0-1 and 0-3 feet exposure intervals for this area. However, the data from the test pit soil samples were used for analytes that were not analyzed for in 2009. Specifically:
    - The data from the four gully test pit samples are included in the assessment of potential risk to ecological or human receptors exposed to surface and shallow soil intervals (0-1 and 0-3 feet bgs) except for o-xylene, toluene, PCE, and PAHs.
    - All the data from the four gully test pit samples are included in the 0-10 feet bgs interval, which is only applicable to human receptors.
    - The data from the two mercury vapor-lamp test pit samples were used in this RI Report and will be used in the RAs to assess risk to ecological and human receptors exposed to surface, shallow, and deeper soil intervals (0-1, 0-3, and 0-10 feet bgs) since there is no way to assign a depth at which the results for these samples occur.

5.2 Upland Operable Unit

Multiple investigations have been conducted by the USACE and its contractors to evaluate the environmental conditions in the Upland OU. As discussed above, the Upland OU includes four AOPCs (Figure 1-4):

- Landfill AOPC
- Sandblast Area AOPC

- Pistol Range AOPC
- Bulb Slope AOPC

Historical investigations of each are discussed below.

5.2.1 Landfill AOPC

5.2.1.1 Landfill Site Inspection – August/September 1998

The purpose of the initial Landfill Site Investigation (SI) was to assess the potential for historical disposal practices to have adversely impacted the environment and to assess whether additional investigation or remediation was necessary (Tetra Tech 1998). Specific areas of concern that were addressed during the SI included the Landfill, a pesticide/herbicide mixing area located just south of the Landfill, and the shorelines proximate to Bradford Island Landfill. The SI included:

- Summary of the USACE historical aerial photograph review of the Landfill site between 1936 to 1982.
- Summary of the findings of the USACE employee interviews, documenting historical waste disposal practices.
- Collection and analysis of four surface soil samples (three from background locations and one from downgradient of the pesticides mixing area)
- Collection and analysis of 10 subsurface samples from eight test pits (TP1 through TP8) and one soil boring (SB3) located within the Landfill footprint
- Collection and analysis of three samples of building materials (found within the Landfill test pits) for the presence of asbestos
- Installation and sampling of four groundwater monitoring wells (MW1, MW2, MW3, MW4)
- Completion of a visual survey of groundwater seeps along the north, east and south shores of Bradford Island, and the attempted collection of Columbia River sediment samples from the nearshore areas of Bradford Island

The SI report concluded that past disposal practices have impacted soil and groundwater in the Landfill with petroleum hydrocarbons, organochlorine pesticides, PCB Aroclor 1260, PCE, SVOCs, arsenic, and lead. Landfill debris encountered in the test pit excavations included mercury vapor lamps, electrical equipment, and asbestos-containing materials. None of the materials encountered in the excavations were removed. Additionally, no groundwater seeps were identified during a visual survey of the sloped banks of Bradford Island in the vicinity of the landfill during September 1998. Supplementary investigation of the Landfill was deemed necessary in order to evaluate potential remedial alternatives. The analytical results are included in Appendix A; however, the analytical results were not utilized in this RI Report for multiple reasons (i.e., sample reporting limits do not meet established data quality objectives, depth of soil samples incompatible with target depths needed for risk evaluations, etc).

5.2.1.2 Landfill Supplemental Site Inspection – 1999/2000

URS conducted an SSI of the Landfill for the USACE during 1999 and 2000. The purpose of the SSI was to augment information presented in the 1998 SI report, fill data gaps, conduct a risk

evaluation, and provide a list of alternatives for the long-term management of the Landfill. The SSI (URS 2000) included:

- Collection and analysis of 10 primary surface soil samples from Landfill AOPC (BIL01SSI, etc.)
- Installation of groundwater monitoring well (MW-5) in September 1999
- Collection and analysis of groundwater samples from the four wells (MW-1 through MW-4) in July 1999 and from five wells (MW-1 through MW-5) in November 1999, and January 2000
- Additional visual assessment for groundwater seeps, and the collection of seep soil and water samples
- Erosion potential evaluation
- A site survey to facilitate completion of a biological characterization
- A screening level human health and ERA

Analytical results from this investigation are included Table 5-1 and sample locations are shown in Figure 5-1. Results from this, and all subsequent investigations at the Landfill AOPC (discussed below) were included in this RI. The Draft SSI report (URS 2000) concluded that surface and subsurface soils contained relatively low concentrations of VOCs, SVOCs, metals, chlorinated herbicides, organochlorine pesticides, and PCBs. Groundwater contained relatively low concentrations of VOCs, SVOCs, petroleum hydrocarbons, and metals. One seep was found and results indicated that low concentrations of metals were detected in the seep water.

The SSI report (URS 2000) also included a preliminary risk screening for human health and ecological receptors based on landfill contamination. The report identified maintenance workers and on-site construction/excavation workers as human receptors that could be affected by inhalation of, incidental ingestion of, or dermal contact with surface and subsurface soil. Since groundwater is not used at the site as drinking water, it was not included in the preliminary human health screening.

The report identified three preliminary potential exposure pathways for aquatic and terrestrial ecological receptors: incidental ingestion of groundwater discharged to the Columbia River, dermal contact with groundwater discharged to the Columbia River, and incidental ingestion of on-site surface soil. Ecological and human health risk screening was conducted and concluded that soil and groundwater posed no risk to human receptors. The report also concluded that there were localized exceedances of risk-based screening levels for ecological receptors.

Based on DEQ's comments on the conclusions made in the Draft SSI report, USACE elected not to finalize the report. The DEQ and USACE agreed that additional investigation and analysis were necessary to address DEQ comments on the SSI report.

5.2.1.3 Slope Stability Assessment – 2001

The discovery of PCB-containing light ballasts along the shoreline during the SSI prompted additional investigations into the nature and extent of the debris, and into the potential for environmental impacts from these materials on ecological receptors in the Columbia River. The light ballasts found along the shoreline were thought at that time to have eroded from the

Landfill. URS conducted a slope stability assessment of the steep shoreline along the landfill in May 2001 to determine whether there were potential for landfill wastes to be transported from the landfill into the Columbia River by slope failures (URS 2001). The stability assessment findings included:

- The shoreline along the north slope of the landfill ranges from vertical to over-vertical, to a steep incline.
- Bedrock outcrops of conglomerate, sandstone, and limited siltstone (part of the slide block) are exposed along the north slope. The potential for bedrock failure is low.
- The contact between the slide block and overlying soils along the slope varies from less than 5 feet to 20 feet bgs.
- Where over-steepened, soils along the north slope are marginally stable, and have failed in the past, in one area.
- USACE personnel familiar with this area have not observed significant slope retreat over the past few years.
- There is no evidence that significant and/or multiple rock slope failures have occurred along the north slope of the island. Consequently, the possibility that slope failure transported waste from the landfill into the river is low.

In conjunction with the stability assessment, underwater surveys to locate and map the extent of all waste materials in the river were conducted in October and November of 2000, and in May 2001. All wastes identified were removed in December 2000 and March 2002 (URS 2001; URS 2002a,b,d). These activities are discussed in more detail in Section 6.2.2.

5.2.1.4 Draft Level I Ecological Scoping Assessment and Human Health Problem Formulation – 2002

A Draft Level I Ecological Scoping Assessment and Human Health Problem Formulation report was completed in 2002 for the Bradford Island Landfill (URS 2002d). This report discussed (qualitatively) potentially complete exposure pathways and identified COIs for human and ecological receptors. In conclusion, the report recommended that a Level II Ecological Screening Assessment be performed to provide a more thorough evaluation of the potentially complete and significant exposure pathways for ecological receptors based on soil, sediment, groundwater, surface water, and food-web contamination. The report also recommended that a BHHRA be performed.

5.2.1.5 Phase II Supplemental Landfill Site Investigation – 2001/2002

The objective of the additional site characterization investigation was to collect site information to assist in the characterization of known or suspected potential environmental concerns at the Landfill (Site Characterization Report, Bradford Island Landfill; URS 2004a). The additional site characterization field activities included:

- Collecting and analyzing 10 primary soil samples from a test pit in the gully area (BIL13 through BIL22)

- Removing mercury vapor lamps from a known area of disposal at the Landfill, and collection and analysis of seven primary soil samples from the mercury vapor-lamp excavation area (BIL05 through BIL11)
- Completing a geophysical evaluation of the Landfill using electrical resistivity and seismic refraction methods to estimate the extent of the Landfill
- Installing and developing four monitoring wells (MW-6, MW-7, MW-8, MW-9)
- Collecting and analyzing nine primary groundwater samples (one each) from MW-1 through MW-9
- Collecting and analyzing six primary soil samples at the Landfill (BIL24, BIL26, BIL27, BIL30, BIL31, BIL32)
- Collecting and analyzing six composite soil samples excavated from the gully test pit (BIL01TPG, BIL02TPG, BIL03TPG, BIL05TPG) and the mercury vapor-lamp test pit(BIL28TPM, BIL29TPM), which were then backfilled at their respective test pits at the Landfill

Additional tasks used to refine the CSM included:

- Developing a water budget for the Landfill area
- Determining the thickness of Landfill material and the thickness of unconsolidated material above the slide block
- Determining aquifer characteristics

The site characterization report (URS 2004a) concluded that wastes disposed of within the Landfill include household waste and project-related wastes such as grease, light bulbs, sandblast grit, and miscellaneous metal. The Landfill is located within a 0.63-acre area. Landfill materials and visually impacted soils did not appear to extend beyond 15 feet in depth. The estimated volume of the Landfill ranged from 9,900 to 7,500 cy, whereas the estimate for the actual debris may be as low as 3,758 cy plus any sandblast grit.

A minimal quantity of electrical debris were observed in the Landfill when compared to the amounts removed from within the river or on the shore of the island. There was no evidence that significant and/or multiple past slope failures have occurred along the north slope of the island. Consequently, the possibility that slope failures have transported electrical debris to the river was considered low to negligible.

The Landfill wastes were considered to have impacted soils primarily, with petroleum hydrocarbons, and select VOCs, SVOCs, metals, and PCBs. This resulted in groundwater being impacted with low levels of VOCs, SVOCs and metals. Groundwater was expected to discharge from the site into the river predominantly through diffuse flow or through fractures on the north side of the island.

Analytical results for this investigation are included Table 5-2 and the sample locations are shown in Figure 5-1.

5.2.1.6 Level II Screening Ecological Risk Assessment and Baseline Human Health Risk Assessment – 2004

A Level II Screening ERA and BHHRA report (URS 2004b) was completed for the Bradford Island Landfill. The Level II report concluded (with caveats) that risks to human health at the site were considered acceptable under current land use conditions and that risk reduction measures were not necessary to protect human health. The primary concerns identified for ecological receptors were the potential for direct exposure toxicity to birds and mammals from contact with Landfill soils. Based on some exceedances of ambient water quality criteria (AWQC) by site groundwater concentrations, additional evaluation of the potential for groundwater to impact surface water quality of the river was recommended.

The Level II report deferred a quantitative evaluation of risks posed by the aquatic habitat to after the sediment removal. Consequently, an EE/CA (URS 2005) for in-water sediment removal work was prepared in 2005 and provides an evaluation of human health and ecological risks related to the aquatic environment (primarily from contaminated sediment).

5.2.1.7 Upland Source Evaluation – January to August 2007

In 2007, an Upland Source Evaluation for the Landfill was conducted, which qualitatively evaluated the need for upland source control measures (URS 2007c,d). The focus of the evaluation was on direct transport of impacted soil to surface water, either through erosion and transport by storm water or by mass wasting. In April 2007, a limited soil sampling investigation between the Landfill and the river was conducted.

Six surface soil samples from the north slope of Bradford Island between monitoring well MW-6 and the Columbia River (BIL01USE, BIL02USE, BIL03USE, BIL07USE, BIL08USE, and BIL09USE). Three additional samples were taken on the eastern tip of the island where debris was removed in 2002, just upslope of former inwater pile #1 (BIL04USE, BIL05USE, and BIL06USE). Sample locations are shown in Figure 5-2 and analytical results are tabulated in Table 5-3. These nine samples, included in this RI report, were inadvertently omitted from the Upland DSR.

Undercutting was observed along the waterline at the north slope suggesting that historical mass wasting likely occurred. The Upland Source Evaluation for the Landfill concluded that since both slopes are covered with surface vegetation, there appears to currently be a low potential for soil migration via overland transport but that a quantitative erodibility study would be needed to further assess the potential for soil loss (URS 2007d).

5.2.2 Sandblast Area AOPC

The “Sandblast Area” is an informal name that has been used during past investigations to describe the former sandblast building and the area around the building where spent blast media (sandblast grit) has been placed on the ground surface or where other potential contamination sources may be present. Figure 3-4 depicts the Sandblast Area AOPC. As discussed in Section 3.5.1 and 4.1, potential contamination sources include:

- Former disposal area for spent sandblast blast grit
- Former HMSA located east of the equipment building
- Former transformer maintenance area east of the former sandblast building

- An inferred release of VOCs (i.e., PCE) from an AST historically located in the vicinity of the current HMSA
- Laydown area used for current storage of industrial equipment and materials located along the north and south sides of the landfill access road

5.2.2.1 Stormwater System Sampling and Cleaning–2001 to 2002

Solid materials from the catch basins and near the stormwater system outfalls on the northern perimeter of the Sandblast Area AOPC were sampled in May 2001. Based on the results of the catch basin and stormwater system outfall sampling, the stormwater system was identified as a potential pathway for conveying contaminants form the Sandblast Area AOPC to the river. In October 2001, the USACE cleaned the sediment from the stormwater system, replaced the filter fabric socks that line each catch basin, and characterized and disposed of the waste generated during the cleaning process.

Since the stormwater system was identified as a potential pathway for conveying contaminants form the Sandblast Area to the river, the USACE developed and implemented a regular inspection and maintenance program to prevent the discharge of sediment into the storm drain system (e.g., replacement of the filter socks on a periodic basis). Additional details regarding the stormwater system sampling and cleaning activities can be found in the In Water Investigation Report (URS 2002a) and the Storm Water Drain Cleaning Summary Technical Memorandum (URS 2002e). Since the stormwater system solids that were tested have been removed and disposed of, this data is not used in this RI Report.

5.2.2.2 Preliminary Assessment/Site Inspection Sandblast Area, Transformer Release Area, and Former Drum Storage Area – 2001/2002

The PA/SI of the Sandblast Area was conducted in 2001 to aid in the characterization of environmental concerns associated with the transformer maintenance area, and the former HMSA (also referred to as the former drum storage area) (URS 2002c). The SI included:

- Twenty-seven sandblast grit/soil samples collected from northeast, east, and south east of the former sandblast building (DSA01 through DSA12, SBB01, SBB03 through SBB07, SBB10 to SBB12, SBB13, SBB14, SBB17, SBB18, SBB23, and SBB24). Some of these samples were labeled as "sandblast" based on field observations to indicate samples containing higher quantities of sandblast; however, samples labeled as both "sandblast" and "soil" were treated as soil in this RI.
- Fourteen soil samples were collected near catch basin #1 (CB-1) and along the shoulders of the access road northeast of the former sandblast building (TRA01 through TRA07, TRA09, TRA11, TRA12, SBB09, SBB13, SBB15, and SBB16).

Sample locations are shown in Figure 5-2 and the associated analytical results are shown in Table 5-4. The burn pit located southeast of the former sandblast building and a septic tank northwest of the building was identified at that time as additional potential sources of contamination within the Sandblast Area AOPC. In addition, evidence of localized solvent-impacted soil was discovered south of the current HMSA. A soil sample (SBB18) collected below the grit-soil interface at approximately 2.5 feet bgs at this location exhibited a strong VOC odor and detections of VOCs and SVOCs.

The PA/SI report estimated that an area of approximately 20,000 square feet and 1 to 3 feet deep (1,500 to 2,000 cy) might be regulated as hazardous waste if excavated based on lead and chromium concentrations (URS 2002c). The total volume of sandblast grit present was estimated at between 1,410 and 2,025 cy. Figure 3-4 shows the approximate extent of the primary sandblast grit disposal area; however, evidence of sandblast grit was also observed in surface soils further to the north.

5.2.2.3 Soil Sampling – 2004

In April and May 2004, the USACE cleared the vegetation and graded an area of approximately 1,600 square feet near CB-1 (Figure 3-4). This work was performed to provide space for the storage of dam gates on several concrete piers. Less than 6 inches of topsoil were excavated by the USACE during vegetation removal. The vegetation and some soil connected to the roots were temporarily stockpiled in a roll-off dumpster.

After grading the area, USACE personnel collected 18 surface soil samples from the area that had been cleared and six soil samples from the dumpster. These samples were submitted for leachable lead and chromium analysis by TCLP. Analytical results are available in Appendix B of the SSI, Sandblast Area (URS 2006a). Based on the results, the soil in the dumpster was disposed of as hazardous waste at the chemical waste landfill in Arlington, Oregon. The TCLP results were not used in this RI Report because the TCLP analysis uses a simulated leachate sample to evaluate leachable COI concentrations for waste handling and disposal requirements.

5.2.2.4 Supplemental Site Inspection – 2004 to 2006

The SSI of the Sandblast Area was conducted in November 2004 to assist in the characterization of known or suspected potential environmental concerns at the Sandblast Area. The investigation method details and analytical results were summarized in the SSI, Sandblast Area (URS 2006a). The investigation included (Figure 5-2):

- Twenty four soil samples collected using hand augers and direct push borings near the current HMSA, adjacent to the river, outside of the sub basin captured by the former sandblast building stormwater system, from within the catch basins, around the septic tank, and beneath the former burn pit (DP1 though DP12 and HA1 through HA12).
- Twelve groundwater samples were collected from direct-push borings: four borings were drilled along the Landfill access road (DP1 through DP4), five borings were drilled in the drain field for the former sandblast building septic system (DP5 through DP9), and three were drilled in the presumed downgradient direction adjacent to the HMSA (DP10 through DP12).

The SSI concluded that in addition to the metals and butyltins, detected during the previous investigations, several other COIs were detected in the Sandblast Area AOPC. These included PCBs, SVOCs, and VOCs. The sandblast grit is not believed to be the source of contamination for these COIs. The report concluded that the four potential sources of PCB, SVOC, and VOC contamination were (URS 2006a):

- Incidental spills of hazardous materials at the southwest corner of the hazardous materials storage area.

- Storage of dam-related equipment along the Landfill access road. Oil-stained soil, metal painted with lead-based paint, and potentially PCB-containing equipment and insulators were observed in this area in 1996.
- Disposal and incineration of wastes in a former burn pit at the east end of the Sandblast Area.
- Transformer maintenance documented in the PA/SI (URS 2002c). A small release of PCB-contaminated oil occurred in 1995 at the paved area east of the former sandblast building during a transformer rehabilitation project.

Additionally, low levels of petroleum hydrocarbons, VOCs, SVOCs, butyltins, and pesticides were detected in several groundwater samples in the Sandblast Area AOPC.

During a previous investigation, air compressor blow-down water was identified as a potential source for lead and bis(2-ethyl hexyl) phthalate (B2EHP) identified in river sediments proximate to a drainage outfall north of the former sandblast building (URS 2002c). As part of the SSI, one sample of blow down water was collected from a pipe that conveys compressor blow-down water from the current sandblasting area in the service center building to the drainage ditch near the former sandblast building. The blow-down water appeared clear, did not have a sheen, and had no unusual odors. Neither B2EHP nor lead were detected in the blow-down water sample, but low levels of three SVOCs, four VOCs, and chromium were detected (URS 2006a).

5.2.3 Pistol Range AOPC

During the PA/SI for the Pistol Range, conducted in 2002, 73 soil samples were collected from 42 sample locations (in some locations samples were collected at different depths). The area investigated was approximately 200 feet long and between 20 to 30 feet wide (approximately 4,550 square feet). Figure 5-3 depicts the location of the Pistol Range and former firing shed in relationship to the sample locations. Table 5-6 tabulates the analytical results. The investigation method details were summarized in the PA/SI Report for the Former Pistol Range (URS 2003a).

Groundwater data were not collected during the PA/SI. In the preliminary screening of the data, the maximum soil analytical concentrations indicated that lead was the only metal elevated above relevant screening criteria at the time (USEPA Region 9 Preliminary Remediation Goals [PRGs]), and it was found primarily near the former firing shed and around the backstop (URS 2003a). These areas appeared to be relatively small (600 square feet around the firing shed, and 1,400 square feet of soil around the backstop) and shallow (impacts likely extend up to 2 feet bgs). The report also concluded that concentrations of both lead and zinc exceeded sediment screening values protective values for the benthic community and could cause a potential concern if the upland soils were transported to the river (URS 2003a).

5.2.4 Bulb Slope AOPC

A reconnaissance investigation of the Bulb Slope area was conducted in November 2002. The investigation and findings are described in the Draft Bulb Slope Reconnaissance Investigation and Evaluation of Potential Remedial Options (URS 2003b). The investigation included soil samples collected from eight locations. The sample locations are shown in Figure 5-4 and analytical results and provided in Table 5-7.

The investigation report concluded that PCBs as Aroclor 1260, lead, and mercury are present in soils within the area of visually observed glass debris at the Bulb Slope. The report estimated that approximately 95 to 125 cy of debris and impacted soil is present at the Bulb Slope on top of a bedrock base (URS 2003b).

5.3 River Operable Unit

The historical River OU data (samples collected prior to 2007) are not used in the risk assessments are therefore not discussed in detail in this report. The one exception is the Forebay smallmouth bass collected in 2006, are discussed in Section 6.0. The data for samples collected from the River OU from December 2000 forward are available in the project database (Appendix A) and tabulated historical data are included in Appendix G.

The USACE completed sediment evaluations associated with dredging and construction work related to the Bonneville Project in 1991 (USACE 1991), 1997 (USACE 1997b), 2001 (unpublished USACE study), and 2002 (URS 2002f).

In October and November 2000, underwater dive surveys were conducted due to the discovery of light ballasts on-shore on the north side of the island adjacent to the Landfill. The surveys identified waste-related items submerged in the Columbia River in three distinct piles, just offshore of the Landfill. As described in Appendix E of the In Water Investigation Report approximately 60 electrical items were removed from Debris Pile #1 and four sediment samples were collected during the recovery activities in December 2000 (URS 2002a).

A preliminary in-water investigation was conducted in May 2001 to evaluate sediment, clams and crayfish near the waste items in order to plan for a removal of the items (URS 2002a). Waste-related items were removed in February and March 2002 (URS 2002b). Additional investigations were completed in 2002 and 2003 to assess the extent of sediment related impacts from the waste-related items (URS 2003c and URS 2004c). Based on the results of the sediment investigations within the Forebay the EE/CA for sediment removal was completed in 2005 (URS 2005). The conclusion of the EE/CA was to perform dredging near the former debris pile areas along the tip and the northern shoreline of Bradford Island.

In April 2006, additional high volume surface water and sediment data were collected to support the EE/CA following the Surface Water and Sediment Sampling for Non-Time-Critical Sediment Removal Action QAPP (USACE and URS 2006). Analytical results were presented in the Removal Design Data Gaps Surface Water and Sediment Sampling Technical Memorandum (URS 2006b). A detailed summary of the historical investigations conducted in the River OU is presented in the RI/FS MP (URS 2007a).

5.4 Summary

This section summarized the investigations that occurred prior to the September 2007 RI/FS MP (URS 2007a). The relatively static physical environment of the Upland OU means that environmental data collected over the past decade can be considered representative of current conditions. Except where data quality does not meet the standards outlined in the RI/FS MP (URS 2007a), analytical results from investigations in the Upland OU from 1999 to 2009 were included in the RI data set and were evaluated in the risk assessments (exceptions are noted above). The results of Upland OU investigations that were conducted following the RI/FS MP are summarized in the next section (Section 6.0).

The physical environment of the River OU is much more dynamic. As discussed previously, the electrical equipment and debris and the majority of the contaminated sediment were removed from the river between 2001 and 2007, and water movement and human activities have redistributed sediment within the Forebay. Additionally, the sampling methods used to collect the historical data in the River OU are not comparable to the recent sampling which was conducted in accordance with the procedures outlined in the River OU QAPP (URS 2007b), Revised Sculpin Analysis Strategy Technical Memorandum (URS 2009b), and In Water QAPP Addendum (URS 2009c). In order to focus on the current river conditions, only analytical results from investigations in the River OU after 2007, with the exception of smallmouth bass collected in 2006, were included in the RI data set and were used in the risk assessments. The results of River OU investigations that were conducted following the RI/FS MP, as well as the Forebay smallmouth bass collected in 2006, are summarized in the next section (Section 6.0).

6.0 RECENT SITE INVESTIGATIONS

Recent site investigations are defined in this report as investigations occurring after the completion of the September 2007 RI/FS MP (URS 2007a), which described the overall site investigation management plan. The goal of the RI/FS MP was to provide a foundation for subsequent investigations to support the preparation of this RI report, the HHRAs and ERAs, and to permit evaluation of engineering alternatives to address site contamination. Section 8.0 of the RI/FS MP describes the data gaps for the Upland and River OUs. Data gaps were identified under three categories: gaps with respect to understanding nature of contamination, gaps with respect to understanding the extent of contamination, and gaps with the respect to the ability to perform risk evaluations.

Data gap sampling for the Upland and River OUs was completed in 2007 through 2009, following the guidance of the Upland OU QAPP (URS 2008a), Upland QAPP Addendum (URS 2009a), River OU QAPP (URS 2007b), Revised Sculpin Analysis Strategy Technical Memorandum (URS 2009b), and In Water QAPP Addendum (URS 2009c). Upon completion of the data gap sampling, two reports were prepared evaluating whether the objectives of the RI/FS MP were met. The Upland OU DSR (URS 2009e) and the River OU DSR (URS 2009d) concluded that the data met project objectives outlined in the RI/FS MP and the data were sufficient and usable for the completion of this RI and the risk assessments. The following sections briefly summarize the data gap sampling investigations conducted in the Upland and River OUs. The data presented in this section are used in the risk evaluations (unless otherwise noted).

The comprehensive data set used for the RI includes historical samples that meet data quality objectives (Upland OU only) and recent samples (Upland and River OUs). Appendix G provides the historical data not utilized in the RI due to poor data quality or because historical samples are no longer representative of current conditions. The historical investigations are discussed in Section 5.0, and recent investigations are described in this Section. The total number of samples included in this RI for each sample matrix are presented in Table 6-1.

Section 5.1 summarizes the processing treatments for the Upland OU and River OU data necessary for use in the RI Report. Processed and unprocessed data are provided in Appendix A, along with a complete enumeration of the processing treatments. Appendix E provides the laboratory reports and Appendix F provides the data validation reports. Appendix H presents the results of the individual congener analyses, along with the methodology used for summing total PCBs as congeners, total PCBs as Aroclors, and total PAH, and tables with the sums for each sample.

6.1 Upland OU

This section briefly summarizes the investigations and sampling that occurred after the September 2007 RI/FS MP (URS 2007a). Analytical data from these investigations is incorporated in this RI Report and used in the risk evaluations.

6.1.1 Landfill AOPC

The recent fieldwork completed in the Landfill AOPC included the sampling of four quarters of groundwater data and the collection of additional surface and near-surface soil samples from the gully area (URS 2008a).

The field activities included:

- Collection/analysis of four quarters (March 2008, July 2008, October 2008, and January 2009) of groundwater samples from the nine monitoring wells located in the Landfill AOPC
- Survey for groundwater seeps during each quarterly groundwater event. Collection/analysis of samples from each observed seep along with the surface water immediately adjacent to the seep.
- Collection/analysis of soil samples from depth intervals of 0-1 foot bgs and 1-3 feet bgs from four test pits (L1 though L4) in the gully area.

Details of the well installation of the Sandblast Area AOPC groundwater wells are included in the Groundwater Monitoring Well Installation Report (URS 2008b). The results for the groundwater sampling were reported quarterly, with each successive quarterly report incorporating data from the previous reports, therefore the fourth quarter report will be referenced here (URS 2009g). Finally, the results for the soil samples collected from the gully area were included in the Upland OU Data Gap Sampling Report (URS 2009f). Sample locations are shown in Figure 5-1 and the analytical results are tabulated in Table 6-2.

6.1.2 Sandblast Area AOPC

The data gaps identified for the Sandblast Area AOPC in the RI/FS MP (URS 2007a) included the need for additional groundwater, soil, and soil gas samples. Following the publication of the RI/FS MP, routine maintenance activities occurred in July 2008 that included scraping and stockpiling surface soils to extend the eastern portion of the laydown area. The actively exposed soils appeared to have tar-like residue (URS 2009a). The USACE elected to performed additional site investigations on the newly exposed soils, which are included in the discussion below.

The recent field activities in the Sandblast Area AOPC included:

- Installation of five groundwater monitoring wells in the Sandblast Area AOPC (MW-11 through MW-15).
- Collection/analysis of four quarters (March 2008, July 2008, October 2008 and January 2009) of groundwater samples from the five monitoring wells located in the Sandblast Area AOPC.
- Collection of surface and near surface soil samples from eight sampling stations (SB1 through SB8) within known areas of sandblast grit disposal to be sieved into two size fractions and analyzed for lead only.
- Collection/analysis of five soil gas samples (SB10 through SB14).

- Collection/analysis of five soil samples from five test pits in the newly exposed laydown area (LD1 through LD5).
- Collection/analysis of six surface soils from stockpiled soils in the laydown area (LD6 through LD11).

Details of the well installation of the Reference Area groundwater well are included in the Groundwater Monitoring Well Installation Report (URS 2008b). The results for the groundwater sampling were reported quarterly, with each successive quarterly report incorporating data from the previous reports, therefore the fourth quarter report will be referenced here (URS 2009g). The sampling activities and results are included in the Upland OU Data Gap Sampling Report (URS 2009f). Sample locations are shown in Figure 5-2 and analytical results are tabulated in Table 6-3.

6.1.3 Pistol Range AOPC

The recent fieldwork completed in the Pistol Range AOPC included the collection and analysis of grab groundwater samples and lagoon sediment samples.

The field activities included:

- Collection/analysis of two grab groundwater samples (PR1 and PR2D)
- Collection/analysis of five sediment samples from the Pistol Range Lagoon (PR4 through PR8).

The sampling techniques and results are included in the Upland OU Data Gap Sampling Report (URS 2009f). Sample locations are shown in Figure 5-3 and analytical results are tabulated in Table 6-4.

6.1.4 Bulb Slope AOPC

No data gaps were identified for the Bulb Slope AOPC in the RI/FS MP (URS 2007a); therefore, additional sampling was not performed at this AOPC.

6.1.5 Reference Area

The objective of the Reference Area was to provide site-specific background concentrations of inorganic COIs in soil and groundwater (URS 2008a). The samples were also analyzed for selected organic analytes to evaluate the potential contribution, if any, of non-site-specific sources to organic COI to site risk.

The field activities for the Reference Area included:

- Installation of the Reference Area groundwater monitoring well (MW-10)
- Collection/analysis of four quarters (March 2008, July 2008, October 2008 and January 2009) of groundwater samples from the Reference Area monitoring well.
- Collection/analysis of fourteen surface soil samples (R1 through R14)

Details of the well installation of the Reference Area groundwater well are included in the Groundwater Monitoring Well Installation Report (URS 2008b). The results for the groundwater sampling were reported quarterly, with each successive quarterly report incorporating data from

the previous reports, therefore the fourth quarter report will be referenced here (URS 2009g). The sampling techniques and results are included in the Upland OU Data Gap Sampling Report (URS 2009f). Sample locations are shown in Figure 6-1 and analytical results are tabulated in Table 6-5.

6.1.6 Upland OU Erodibility Studies

As described in the RI/FS MP (URS 2007a), the identification of erodible soils was identified as a data gap for the Upland OU. Erodibility surveys were carried out in 2009 for each of the three primary AOPCs, including the Landfill, Sandblast Area, and Pistol Range AOPCs. A visual survey was performed for the Bulb Slope AOPC because this AOPC is a steep, rocky, vegetated slope on the north shore of Bradford Island, which was not suitable for the model used in the Erodibility surveys of the other AOPCs.

The objective of these surveys was to estimate the volume of sediment, and associated mass of COIs, potentially transported from each of the AOPCs to the Columbia River. Field surveys of the site were conducted on January 26 and February 5, 2009 (URS 2009f). The erodibility study identified only a limited portion of the Sandblast Area AOPC, where soils had been temporarily exposed during construction activities, as having a potentially complete pathway associated with stormwater runoff to the river. No currently-erodible soils were identified in the Landfill, Bulb Slope, or Pistol Range AOPCs. In a follow-up sampling event in March, 2009, surface soil samples were collected from the potentially erodible soils at the Sandblast Area AOPC. This included:

- Collection/analysis of two composite soil samples from the sloped area north of the former sandblast building, near catch basin #2 (CB-2), in the Sandblast Area AOPC. Eight subsamples were composited into sample SB-EUA and sixteen subsamples were composited into sample SB-EUB. VOC analyses were conducted on eight discrete subsamples (SB-EUA-02, SB-EUA-04, SB-EUA-06, SB-EUA-08, SB-EUB-02, SB-EUB-03, SB-EUB-12, and SB-EUB-15).

For further details, see the Erodibility Study presented in Attachment E of the Upland OU Data Gap Sampling Report (URS 2009f). Sample locations are shown in Figure 5-2 and analytical results are tabulated in Table 6-3. As discussed above, since March 2009, this portion of the Sandblast Area AOPC has become revegetated and no longer contains erodible soils.

6.2 River OU

This section briefly summarizes the recent sampling activities, including:

- Sampling of smallmouth bass, sediment, and clam samples in 2006 and 2007 prior to the sediment removal,
- Monitoring during the removal action,
- Post-removal statistically-based sampling in the Forebay and Reference area,
- Sampling of downstream sediment, and
- Targeted sampling in the Forebay (Eagle Creek and Goose Island Slough).

Analytical data from these investigations were used in this RI and the risk evaluations, unless otherwise noted.

6.2.1 Pre-Removal Sampling

In June and August 2006, the USACE collected smallmouth bass (and one sucker composite sample) from the Forebay. The findings were presented in the Forebay and Reference Area Smallmouth Bass Collected June 2006 through May 2008 Summary Report (URS 2008c). Sample locations are shown in Figure 6-2 and the analytical results are included in Table 6-6. These smallmouth bass samples were archived pending collection of the Reference Area smallmouth bass (Section 6.2.3). Data from the Forebay smallmouth bass samples are included quantitatively in the risk assessments. The data from the single sucker sample are considered qualitatively in the risk assessments.

In September 2007, pre-removal sediment and clam samples, from the vicinity of the three former debris piles, were collected following the River OU QAPP (URS 2007b). The pre-removal samples were collected from within the footprint of the planned sediment removal area. Five sediment samples and four co-located clam samples were collected. Clam tissue was scarce at one of the five sediment locations (sample station 4) and therefore could not be collected. The objective of collecting these co-located clam and sediment samples was to enable the estimation of biota-sediment accumulation factors (BSAFs) and to estimate concentrations of PCBs that might be present in the removal area. Analytical results are reported in the Pre-Removal Action Sediment and Clam Sampling Analysis (URS 2008d). Sample locations are shown in Figure 6-3 and the analytical results are included in Table 6-7. These data are not representative of post-removal conditions, but, at the request of TAG members, the data are considered qualitatively in the risk assessments.

6.2.2 Sediment Removal and Monitoring

The preferred option selected during the EE/CA for sediment removal was dredging near the former debris pile areas along the tip and the northern shoreline of Bradford Island (URS 2005). Sediments were removed between October 2 and October 30, 2007 using used diver-assisted hydraulic dredging starting on. The total area dredged was approximately one acre as detailed in the Project Closure Report (HAI 2007) and shown in Figure 6-3. Sediments were dewatered onsite. The process produced dredge effluent water that was treated by gravity separation, particulate filtration and carbon filtration prior to being discharged back to the Columbia River. The sediment was contained on a barge and disposed of offsite.

To assess the potential for impacts to the Columbia River from the dredging operation and the discharge of the treated water (i.e. effluent), a water quality monitoring program was developed and implemented (URS 2007e). The program consisted of sampling the dredge effluent at the point of discharge on a weekly basis during dredging, deploying semi-permeable membrane devices (SPMDs) prior to dredging (e.g. to establish baseline conditions) and during dredging, collecting grab water samples in conjunction with the SPMD deployments, and measuring turbidity during dredging.

Turbidity monitoring results are presented in the Project Closure Report (HAI 2007). Analytical data from dredge effluent, SPMD, and surface water samples collected between August 20, 2007 and November 2, 2007 are summarized in the Water Quality Monitoring Report In-Water

Removal Action (URS 2008e) and are included in the projected database (Appendix A). The dredge effluent samples showed no detectable PCBs in either the particulate or dissolved phase in the dredging return water. The SPMD results showed the dissolved fraction of PCBs in the water column both before and during dredging the activity were at very low levels, on average approximately 30 picograms per liter (pg/L) (URS 2008e). Comparison of the SPMD results between the removal action area and the downstream station indicate that the dredging activity did not have any appreciable effect on the concentration of PCBs in the dissolved fraction of the water column. Since the analytical data collected to monitor the dredging they are not used in the risk assessment and are not discussed further.

6.2.3 Forebay and Reference Area Post-Removal Sampling

While extensive sediment data had previously been collected in the River OU, sampling was focused near the former debris piles and tissue sampling was primarily focused on lower trophic level media. Additionally, these historical samples do not represent current (port-removal) conditions in the Forebay. The RI/FS MP (URS 2007a) identified the following data needs:

- A statistically-based program of collection/analysis of sediment and tissue data from the Forebay to assess the migration of biomagnifying COIs through the food web.
- A statistically-based program of collection/analysis of sediment and tissue data from an upstream Reference Area to establish site-specific background concentrations of inorganic COIs and evaluate the contribution of ambient concentrations of organic COIs to the site-wide risk estimate.
- Collection/analysis of surface water from the Forebay and Reference Area to evaluate surface water impacts in the Forebay
- Collection/analysis of targeted sediment data from the mouth of Eagle Creek, hereafter referred to as the "Eagle Creek" samples, to assess exposure to sediments for human anglers.

In addition, after the preparation of the RI/FS MP, one additional data need was identified:

- Collection/analysis of targeted sediment and tissue (clams, crayfish, and sculpin) data from the slough on the southern side of Goose Island, hereafter referred to as the “Goose Island” samples, to further investigate the presence of PCBs detected in smallmouth bass random Forebay samples.

6.2.3.1 Statistical Sampling of Sediment, Clam, Crayfish, Sculpin and Smallmouth Bass

As described in the QAPP a minimum of 14 samples were required for each media in order to meet the sample size needed for statistical comparison. The target sample size for each media was therefore between 14 and 21 randomly selected sampling stations for sediment, clam, crayfish and sculpin in both the Forebay and Reference Area (URS 2007b).

Sediment and clam tissue were successfully collected in February/ March 2008 from 17 and 19 of the randomly selected stations in the Forebay and Reference Area, respectively (URS 2008f). Crayfish and sculpin trapping at the random stations did not result in sufficient sample mass to generate the minimum number of samples (i.e., 14 each in the Forebay and Reference Area). Therefore, the traps were set in nearby areas outside the original randomly selected sampling

stations which posed more suitable habitat. This strategy was successful for crayfish, but insufficient sculpin were obtained in during the February and March 2008 field activities (URS 2008g).

Additional sculpin collection in both the Forebay and Reference Area was carried out by the USGS between July and October 2008 and resulted in sufficient sculpin mass for analysis. A geographical-based sculpin compositing scheme was proposed by the USACE (URS 2009h). Based on comments received from the TAG during the January 28, 2009 TAG meeting, the final compositing scheme was selected as described in the Revised Sculpin Analysis Strategy Technical Memorandum (URS 2009b).

As described in Section 6.2.1, smallmouth bass were collected in the Forebay in June and August 2006, prior to sediment remediation and archived pending collection of the Reference Area smallmouth bass. Smallmouth bass were collected from the Reference Area in October and November 2007 and May 2008 (URS 2008c). Due to the relatively large home range of the smallmouth bass, sample locations were not restricted to the 21 randomly selected sampling stations. Additionally, due to a lack of suitable habitat, insufficient smallmouth bass were caught within the geographical boundary of the Reference Area, so the data set includes bass caught further upstream (Figure 6-2).

Multiple data deliverables were submitted (URS 2008c,f,g; URS 2009i,j). The number of samples in both the Forebay and Reference Area met the statistically-required minimum sample size for sediment, clams, crayfish, sculpin, and smallmouth bass (Table 6-1). Analytical results for sediment and tissue media collected in Forebay and Reference Area are presented in Tables 6-6, 6-8 through 6-11 and are included in the project database, Appendix A. Sample locations for sediment and tissue media collected in the Forebay and Reference Area are presented in Figures 6-2, 6-3, and 6-4.

Analytical data for the randomly sampled Forebay media (sediment, clam, crayfish, sculpin and smallmouth bass) are used in the risk assessments. Targeted Forebay sample stations (Eagle Creek and Goose Island) are also shown on Figure 6-3. These data are also considered in the risk assessments. Reference Area data are considered in the risk assessments when evaluating the site-related contribution to risk in the Forebay.

6.2.3.2 Surface Water

Five high volume surface water samples were collected in the Forebay and Reference Area between February and March 2008 (URS 2008f and URS 2009f). Sample locations are presented in Figures 6-3 and 6-4. Analytical results are presented in Table 6-12, and are used in the risk assessments.

6.2.3.3 Targeted Sediment Sampling at Eagle Creek

Two sediment samples were collected from the mouth of Eagle Creek in February 2008 (URS 2008f and URS 2009j). Sample locations are shown in Figure 6-3. Analytical results are presented in Table 6-13. These data are used for evaluation of the direct contact pathway in the HHRA.

6.2.4 Downstream Sediment

USACE had not collected sediment samples from depositional areas downstream of the dam prior to 2008. The objective of the 2008 downstream sediment investigation was to assess the potential for sediment impacts related to releases from the site downstream of the dam. Six downstream sediment locations were chosen from likely depositional areas based on hydrodynamic modeling (URS 2007a,b) and are shown on Figure 6-5. Sediment samples were collected in March 2008 from these sample stations (URS 2008f and URS 2009i). Analytical data are presented in Table 6-14.

6.2.5 Goose Island Slough

During the January 28, 2009 TAG meeting, the Goose Island Slough (slough) was identified as a potential data gap by Oregon DEQ and USFWS, due to the fact that many of the Forebay smallmouth bass were collected from the slough, while the other Forebay media were collected from the main channel of the Columbia River. It was suggested by Oregon DEQ and USFWS during the January TAG meeting that additional samples from the slough would aid in filling this potential data gap.

Based on these comments, an Addendum to the River OU QAPP (URS 2009c), detailing the additional slough sampling, was submitted to and reviewed by the TAG. The Goose Island Slough samples were collected in April/May 2009. The sampling locations are shown on Figure 6-3 and the analytical results are presented in Table 6-13. A report summarizing the historical and recent (2009) analytical data from samples located in the slough and in the immediate vicinity of Goose Island was submitted to the TAG (URS 2009k). This report concluded that it is highly probable the elevated PCB concentrations observed in the smallmouth bass collected from the slough were the result of historical body burden associated with the contaminated equipment and sediments that have since been removed from the northern side of Bradford Island. These data are considered in the risk assessments.

7.0 DATA QUALITY ANALYSIS

The tables included in Chapters 5 and 6 represent the comprehensive set of data used in this RI for the evaluation of nature and extent of contamination, as well as the human health and ecological RAs. This chapter discusses the quality of this comprehensive data set and its suitability for the completion of these tasks. The data quality evaluation covers the following topics:

- Sample sizes
- J-flagged Data
- Variable MDLs and MRLs
- MDLs of undetected data greater than SLVs
- MRLs of undetected and J-flagged data greater than SLVs

To assist the reader, the following definitions are provided from the DoD Quality Systems Manual for Environmental Laboratories Version 4.1 (DoD EDQW 2009) provides the following definitions for these parameters:

Method Detection Limit

The MDL is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and it is determined from analysis of a sample in a given matrix containing the analyte.

Method Reporting Limit

The MRL [referred to as the Limit of Quantitation (LOQ) in DoD EDQW 2009] is the minimum concentration of a substance that can be reported with a specified degree of confidence. It is the lowest concentration that produces a quantitative result within specified limits of precision and bias. For DoD projects, the MRL (or LOQ) is set at or above the concentration of the lowest initial calibration standard.

U-flagged Data

A "U" flag, or qualifier, indicates that the analyte was not detected (ND) and is reported as less than the limit of detection defined by the client. The limit of detection has been adjusted for any dilution or concentration of the sample.

J-flagged Data

A "J" flag, or qualifier, indicates that the reported result for an analyte is an estimated value. More specifically, matrix interference was observed or the analyte was detected at a concentration outside the range of values in a laboratory instrument calibration curve between the MRL and the highest successfully analyzed initial calibration standard for that instrument.

For purposes of this project, the limit of detection is defined as the MDL. Therefore, *all references to "detections" indicate that a particular analyte within a given medium was measured at a concentration greater than the MDL. Similarly, all references to "non-detect", or U-flagged, results indicate that an analyte was not detected above the MDL*, unless otherwise noted.

As described in the definition, above, data may be qualified with a J flag for multiple reasons. Although certain data for this project are J-flagged due to matrix interferences and other reasons related to data quality (e.g., holding times exceeded, surrogate failure, and peak identification), this section specifically evaluates data that are J-flagged *because the estimated result is reported between the MDL and MRL*. Evaluation of J-flagged data is important because these results were treated as detected concentrations, and this assumption introduces uncertainties in the RI and RAs, as discussed in Section 7.4.

Section 7.1 presents the data summaries, for each COI and each medium, for each of the Upland AOPCs and the River OU. This section identifies data sets with limited sample size and discusses the use of J-flagged data. Section 7.2 presents the statistics for data sets with at least two detected results and discusses the effect of censoring undetected data at the MDLs versus the MRLs on the resulting statistical parameters (i.e., upper confidence limits [UCLs]). Section 7.3 presents a brief discussion on the relevant SLVs used to screen data for the risk assessments. Section 7.4 presents the data sensitivity analysis, in which the MDLs and MRLs are compared to the SLVs to identify specific COIs and matrices for which the literature-based SLVs may be lower than the sensitivity of current analytical methods.

Since this data quality evaluation was conducted in support of the HHRA and ERA, the evaluation includes not just each of the individual AOPCs, but also the combination of the four AOPCs. This is because certain receptors have the potential to be exposed to all four Upland AOPCs. The combined data set is used for evaluating potential risk to these wide-ranging receptors. The analysis does not consider whether or not the soils in the four AOPCs have different characteristics. The combined data set characterizes the combined potential exposure.

7.1 Data Summary

In this section, the data summary tables for the Upland and River OUs presented in Appendix I are described.

In regards to sample size, any analyte/matrix with a total sample size (detections and non-detects) of fewer than eight is considered to be a limited sample size for which statistical upper-bound estimates of the mean, such as the UCL, cannot be reliably estimated (Singh et al. 2010). In these cases, the maximum detected concentration was used as the exposure point concentration (EPC) for human receptors and all mobile ecological receptors in the risk assessments.

For the population-to-population statistical comparisons to identify COIs that are above Reference concentrations (Section 8.0), a minimum number of 14 samples were required to achieve the desired level of confidence in the results. For data sets with fewer than 14, but more than eight samples, the population-to-population statistical comparisons were conducted, but the level of confidence associated with the results is lower. For these data sets with even fewer samples, the range in concentrations of the site data was compared to the range of concentrations observed in the Reference Area, and box-and-wisker plots were used to determine whether or not site data was higher than Reference Area data. More information is provided in Section 8.0.

7.1.1 Upland OU

Tables I-1, I-2, I-3, and I-4 in Appendix I present the data summaries for the Landfill, Sandblast Area, Pistol Range, and Bulb Slope AOPCs, respectively. The data summary for all four AOPCs

combined is presented in Table I-5, and the Reference Area data summary is presented in Table I-6 in Appendix I. The tables summarize the data by AOPC, medium, analyte group, preparation fraction, analyte, and depth category. The data summary tables provide the number of samples, number of detections, range of detections, and detection rate. All tables also note which data sets are considered limited because they contain fewer than eight samples (a summary of analytes with limited data sets is provided in Table 7-1). They also include the range of MDLs for non-detects, range of MRLs for non-detects and detects below the MRL (i.e., J-flagged), number of non-detects, number of detects between the MDL and MRL (J-flagged), and number of detects above the MRL.

The following text provides a brief description of the data summaries for the four AOPCs.

Landfill AOPC - Among the soil data sets available for the Landfill AOPC (0 to 1, 0 to 3, and 0 to 10 feet bgs), more than eight samples (between 9 and 44 samples) are available for most of the analytes, with the exception of butyltins, a few herbicides and pesticides, and one SVOC (Table I-1). With the exception of aluminum, cobalt, and vanadium for the 0 to 1 and 0 to 3 foot depth intervals, the minimum number of 14 samples was achieved for metals and PAHs for population-to-population statistical comparisons. For the butyltins, limited data sets (fewer than eight samples) only occur with soil from 0 to 1 foot bgs; more than eight samples are available for the other two depth intervals. For the herbicides and pesticides and the one SVOC (total benzofluoranthenes), limited data sets are associated with soil from the 0 to 1 and 0 to 3 feet bgs; and more than eight samples are available for the 0 to 10 foot depth interval. It should be noted that more than 14 samples are available for all soil data sets for both benzo(b)fluoranthene and benzofluoranthene, measured as separate analytes.

For the subset of the samples that comprise the data set for mass wasting soils (0 to 1 foot bgs), more than eight samples are available for most metals, pesticides, PCBs, SVOCs, and PAHs, but not for all herbicides, three TPH mixtures, one SVOC (aniline), and all VOCs.

For groundwater, more than 8 samples are available for all analytes (inorganics and organics) measured as total concentrations in this medium. All groundwater samples from the Landfill were collected from monitoring wells. Dissolved data are available for the 20 metals analyzed for in groundwater, and more than eight dissolved results are available for nine of these metals. Limited data sets are available for seep and surface water data associated with the Landfill for all analytes.

Sandblast Area AOPC – Among the soil data sets available for the Sandblast Area AOPC (0 to 1, 0 to 3, 0 to 10 feet bgs), more than eight samples (between eight and 81 samples) are available for all analytes, including sieved samples analyzed for lead (Table I-2). The minimum number of 14 samples was achieved for all metals and PAHs in soil from these 3 depth intervals, allowing for population-to-population statistical comparison, with the exception of benzo(b)fluoranthene and benzofluoranthene in the 0 to 1 foot bgs data set. Between five and six samples are available for soils collected deeper than 10 feet bgs. In addition, five soil gas samples were collected from the Sandblast Area.

For the subset of the samples that comprise the data set for mass wasting soils (0 to 1 foot bgs), more than eight samples are available for all VOCs, but not for the remaining analytes.

Two types of groundwater data have been collected at the Sandblast Area AOPC: monitoring well samples and direct push grab samples. For groundwater collected from monitoring wells,

more than eight samples are available for arsenic, iron, and vanadium measured as total and dissolved concentrations, and limited data sets are associated with the remaining inorganics (all essential nutrients) that were only measured as dissolved concentrations. More than eight samples are also available for monobutyltin, three TPH mixtures, and the three PAHs analyzed for in groundwater. Fewer than eight samples are available for five of the 65 VOCs analyzed for in groundwater. All monitoring well data for organics were measured as total concentrations.

For direct push groundwater, more than eight samples are available for all metals, which were measured as both total and dissolved concentrations, and for all VOCs (measured as total concentrations). Fewer than eight samples are available for butyltins, pesticides, PCBs, three TPH mixtures, which were measured as total concentrations. SVOCs and PAHs were measured as both total and dissolved concentrations in direct push samples, and fewer than eight samples are available for four of the 68 total samples and 16 of the 67 dissolved samples (none of these are PAHs).

Pistol Range AOPC - More than eight samples (between 10 and 63 samples) are available for the metals analyzed for in soil (0 to 1 foot bgs) of the Pistol Range (Table I-3), with lead having the highest number of samples. Limited data sets are associated with antimony and arsenic. With the exception of antimony, arsenic, molybdenum, and zinc, the minimum number of 14 samples was achieved for metals for the population-to-population statistical comparison.

Fewer than eight samples are available for the four metals (copper, lead, nickel, and zinc) analyzed in lagoon sediment and direct push groundwater samples (measured as both total and dissolved concentrations).

Bulb Slope AOPC - More than eight samples (between 8 and 12 samples) are available for all of the analytes measured in soil (0 to 1 foot bgs) of the Bulb Slope (Table I-4): lead, mercury, PCB Aroclors, and TPH. Population-to-population statistical comparisons were performed comparing metals concentrations in the Bulb Slope AOPC to the Reference Area; however, the level of confidence in the results was lower than desired.

All Four AOPCs Combined - Excluding the soil samples collected from deeper than 10 feet bgs, which are not included in the combined AOPC data set, more than eight samples (between 13 and 199 samples) are available for all of the analytes measured in soil (0 to 1, 0 to 3, and 0 to 10 feet bgs) (Table I-5). The minimum number of 14 samples was achieved for all metals in soil from all three depth intervals for the population-to-population statistical comparisons.

For groundwater collected from monitoring wells, more than eight samples are available for all analytes (inorganics and organics) measured as total concentrations in this medium. Dissolved data are available for the 20 metals analyzed for in groundwater from the Landfill, and fewer than eight dissolved results are available for nine of these metals. Limited data sets are available for seep and surface water data associated with the Landfill AOPC for all analytes.

For direct push groundwater, fewer than eight samples are available for butyltins, pesticides, PCBs, three TPH mixtures, which were measured as total concentrations. Fewer than eight samples are available for four of the 68 total samples and 16 of the 67 dissolved samples analyzed as SVOCs and PAHs (none of these are PAHs).

Upland Reference Area - Fourteen samples are available for the two classes of analytes measured in Reference Area soils (0 to 1 foot bgs) (Table I-6), which is sufficient for statistical comparison to site soils. Fewer than eight background groundwater samples are available for all

analytes since there is only a single monitoring well located in the Reference Area. Groundwater collected from the Reference Area was not intended for statistical comparisons, but rather a semi-quantitative comparison to groundwater from the three AOPCs with groundwater data.

Summary - The minimum number of 14 samples are available for most metals and PAHs in soil, which allows for a population-to-population statistical comparison with Reference Area data at the desired level of confidence. In addition, the minimum number of eight samples required to calculate a 95% UCL (i.e., the EPC used for human receptors and all mobile ecological receptors) was achieved for most analytes measured in media of the Upland OU. For those data sets that were intended for statistical comparisons, the EPC for analytes with fewer than eight samples will be based on the maximum concentration because a UCL cannot be estimated reliably (e.g., tributyltin in the 0 to 1 foot interval for Landfill soils, Table I-12). This is consistent with conventional risk assessment guidance (USEPA 1989). The potential for over prediction or under prediction of risk related to use of the maximum concentration is difficult to assess but does represent the most conservative use of the available data. Some of the data sets identified above with limited sample size were generally not intended for statistical calculations but rather for assessing nature and extent and for gaining a better understanding of fate and transport mechanisms (e.g., Upland to River migration patterns). This minimizes the uncertainty associated with the small data sets.

7.1.2 River OU

Tables I-7, I-8, I-9, I-10, and I-11 in Appendix I present the data summaries for the Pre-Sediment Removal Forebay, Random Forebay, Targeted Forebay, Downstream, and Reference Area, respectively. Data summaries for PCB congeners, when available for a given area, are shown separately from the other analyte groups. The tables summarize the data by area, medium, analyte group, preparation fraction, and analyte. The summary tables provide the number of samples, number of detections, range of detections, and detection rate. All tables also note which data sets are considered limited because they contain fewer than eight samples (a summary of analytes with limited data sets is provided in Table 7-2). For all analytes except PCB congeners, the tables also include the range of MDLs for non-detects, range of MRLs for non-detects and detects below the MRL (J-flagged), number of non-detects, number of detects between the MDL and MRL (J-flagged), and number of detects above the MRL.

The PCB congener tables instead include the range of RDLs for non-detects, number of non-detects below the RDL, range of reported values for EMPC-qualified data, and number of EMPC-qualified results. For PCB congeners, the limit of detection is defined as the RDL or the EMPC (both handled in the same manner), such that *all references to "detections" indicate that a particular congener within a given medium was measured at a concentration greater than the RDL or EMPC*, unless otherwise noted. Similarly, *all references to "non-detect" results indicate that a congener was not detected above the RDL or EMPC*, unless otherwise noted.

Between 15 and 19 sediment, clam, sculpin, crayfish, and smallmouth bass samples are available for the Random Forebay and Reference Area data sets, with the exception of certain chemicals (Tables I-8 and I-11). For example, several metals and all SVOCs could not be analyzed for in sculpin samples due to inadequate tissue mass. With these few exceptions, the minimum number of 14 samples to perform a population-to-population statistical comparison was achieved. In addition, the minimum number of eight samples to calculate a 95% UCL (i.e., the EPC used for human receptors and all mobile ecological receptors) was achieved.

Fewer than eight Pre-Sediment Removal Forebay samples (Table I-7), large-scale sucker samples from the Forebay (Table I-8), Targeted Forebay samples (Table I-9), Downstream samples (Table I-10), and surface water samples (Tables I-8 and I-11) were collected. This was intentional. These samples were not collected for statistical purposes, minimizing the uncertainty associated with the small sample size available. As discussed in Section 6.2, many of these samples were collected to assess presence or absence of certain chemicals in specific media for purposes of nature and extent delineation or were used qualitatively in the risk assessments.

In summary, the number of samples to perform statistical calculations with the desired level of confidence (e.g., population to population comparisons or development a 95% UCL) is available for most analytes and media in the Random Forebay and Reference Area data sets. For the analytes with limited sample sizes, the maximum detected concentrations will be used as the EPC and is subject to some potential for either under prediction or over prediction of risk. Data sets with limited sample size not intended for statistical calculations are also sufficient for assessing nature and extent or for specific qualitative evaluations in the risk assessments.

7.2 Data Statistics

The summary statistics developed for the detected analytes are described in this section.

7.2.1 Upland OU

Tables I-12, I-13, I-14, I-15, and I-16 in Appendix I present the data statistics for the Landfill AOPC, Sandblast Area AOPC, Pistol Range AOPC, Bulb Slope AOPC, and All Four AOPCs Combined, respectively. The tables provide the following statistics for data with at least two detected results: number of samples, number of detections, mean of detections, median of detections, maximum detected value, and 95% UCLs censored at both the MDL and MRL for non-detects.

Table I-17 in Appendix I presents the data statistics for the Reference Area. The table provides the following statistics for data with at least two detected results: number of samples, number of detections, mean of detections, median of detections, maximum detected value, and 95% UCL (if there are at least eight samples).

The objective of this evaluation was to determine how much the 95% UCLs differed depending on what value (the MDL or the MRL) is used to censor the undetected results. Both methods use the J-flagged data at face value. The only difference is whether the undetected data are censored at the MDL, in which case the rank-ordering of the data set puts them below the J-flagged data, or are censored at the MRL, in which case the rank ordering puts them higher than the J-flagged data. In general, censoring using the MDL is the preferred statistical method since it preserves the rank order of the data. However, censoring using the MRL is a more conservative approach.

In the Upland OU, the majority of calculated 95% UCLs are identical or differ by less than 10% for both data censored at the MDLs and those censored at the MRLs, with the following exceptions:

Landfill AOPC

- Soil
    - PCBs – MDL-censored 95% UCLs are **greater** than MRL-censored 95% UCLs by about 18% for Total PCBs as Aroclors (0-1 and 0-3 ft bgs).

  - SVOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 13 to 18% for benzoic acid and butyl benzyl phthalate (0-10 ft bgs).

- Groundwater
  - Butyltins – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 22% for monobutyltin.
  - TPH – MDL-censored 95% UCL is **less** than the MRL-censored 95% UCL by about 21% for gasoline range organics (GRO).
  - SVOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 14% for 2-Methylnaphthalene.
  - VOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 21 to 26% for chloroform and vinyl chloride.

Sandblast Area AOPC

- Soil
  - Metals – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 16 to 25% for beryllium (0-1, 0-3, and 0-10 ft bgs), selenium (0-1, 0-3, and 0-10 ft bgs), and thallium (0-1 ft bgs).
  - Pesticides – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 55% for 4,4'-DDD, 4,4'-DDE, BHC (delta), dieldrin, endosulfan II, endosulfan sulfate, and heptachlor (0-1, 0-3, and 0-10 ft bgs).
  - PCBs – MDL-censored 95% UCLs are **greater** than MRL-censored 95% UCLs by about 23% for Total PCBs as Aroclors (0-1, 0-3, and 0-10 ft bgs).
  - TPH – MDL-censored 95% UCL is **less** than the MRL-censored 95% UCL by about 19% for GRO (0-1 ft bgs).
  - SVOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 11 to 47% for butyl benzyl phthalate (0-1, 0-3, and 0-10 ft bgs), di-n-octyl phthalate (DNOP) (0-1, 0-3, and 0-10 ft bgs), and phenol (0-1 ft bgs). The MDL-censored 95% UCL is **greater** than MRL-censored 95% UCL by 432% for phenol (0-3 ft bgs).
  - VOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 10 to 77% for fourteen VOCs (various depth intervals).
- Potentially Erodible Soil
  - TPH – MDL-censored 95% UCL is **less** than the MRL-censored 95% UCL by about 18% for GRO.
  - VOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 14 to 41% for seven VOCs.
- Groundwater
  - Butyltin and TPH – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by about 29 and 33% for monobutyltin and GRO, respectively.

- DP Groundwater
    - Metals – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 11 to 41% for five metals.
    - SVOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 38% for seven SVOCs.
    - VOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 16 to 44% for eight VOCs.

All Four AOPCs Combined

- Soil
    - Metals – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 17% for beryllium (0-1, 0-3, and 0-10 ft bgs), selenium (0-1, 0-3, and 0-10 ft bgs), and thallium (0-1 ft bgs).
    - Pesticides – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 38% for 4,4'-DDE, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, and heptachlor (various depth intervals). The MDL-censored 95% UCL is **greater** than MRL-censored 95% UCL by 12% for chlordane (technical) (0-10 ft bgs).
    - PCBs – The MDL-censored 95% UCL is **greater** than MRL-censored 95% UCL by about 19% for Total PCBs as Aroclors (0-3 ft bgs).
    - SVOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 10 to 44% for seven SVOCs (various depth intervals).
    - VOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 10 to 44% for seven VOCs (various depth intervals).
- Groundwater
    - Butyltins, TPH, and SVOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by about 27, 23, and 14% for monobutyltin, GRO, and 2-methylnaphthalene respectively.
    - VOCs - MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by about 18 to 34% for chloroform, toluene, and vinyl chloride.
- DP Groundwater
    - Metals – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 11 to 43% for five metals.
    - SVOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 38% for seven SVOCs.
    - VOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 16 to 44% for eight VOCs. The MDL-censored 95% UCL is **greater** than MRL-censored 95% UCL by about 25% for 1,1-dichloroethane.

These results are consistent with the expectation that, in most cases, the 95% UCL calculation is relatively insensitive to the choice of censoring level. Differences generally only occur when there is a large percentage of undetected data. In these cases, the MDL-censored 95% UCLs are generally somewhat lower than the MRL-censored 95% UCLs, but not always. Based on this review, the more statistically-robust calculation (the MDL-censored 95% UCLs) are used in the risk assessment.

7.2.2 River OU

Tables I-18 and I-19 in Appendix I present the data statistics for the Random Forebay and Downstream, respectively. For all analytes except PCB congeners, the tables are identical to those for the Upland OU, and provide the following statistics for data with at least two detected results: number of samples, number of detections, mean of detections, median of detections, maximum detected value, and 95% UCLs (if there are at least eight samples) censored at both the MDL and MRL for non-detects.

For PCB congeners, the tables provide the following statistics for data with at least two detections: number of samples, number of detections (not non-detect or EMPC-qualified), mean of detections, median of detections, maximum detected value, and 95% UCLs censoring non-detects at the RDL and EMPC-qualified data at the reported value. Since MDLs and MRLs are not available for the congener data, there is only on 95% UCL calculation.

In the River OU, the majority of calculated 95% UCLs (for non-congener data sets) are identical or differ by less than 10% for both data censored at the MDLs and those censored at the MRLs, with the following exceptions:

Random Forebay

- Sediment
    - PCBs – The MDL-censored 95% UCL is **greater** than MRL-censored 95% UCL by about 76% for Total PCBs as Aroclors.
    - SVOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 10 to 74% nine SVOCs and Total HPAHs, LPAHs, and PAHs.
- Clam
    - Metals – The MDL-censored 95% UCL is **less** than the MRL-censored 95% UCL by 42% for antimony.
    - SVOCs – MDL-censored 95% UCLs are **less** than the MRL-censored 95% UCLs by 10 to 34% for seven SVOCs.
- Crayfish
    - SVOCs – MDL-censored 95% UCLs are **less** than the MDL-censored 95% UCLs by 10 to 48% for ten SVOCs.
- Smallmouth Bass
    - Metals – The MDL-censored 95% UCL is **less** than the MRL-censored 95% UCL by about 19% for beryllium.

As for the Upland OU data sets, the 95% UCL calculation is relatively insensitive to the choice of censoring level. Based on this review, the more statistically-robust calculation (the MDL-censored 95% UCLs) are used in the risk assessments.

Table I-20 in Appendix I presents the data statistics for the Reference Area. The table provides the following statistics for data with at least two detections: number of samples, number of detections, mean of detections, median of detections, maximum detected value, and 95% upper prediction limit (UPL). These 95% UPL values are used in developing the medium-specific SLVs, as discussed in the next section.

7.3 Screening Level Values and Bioaccumulative Compounds

7.3.1 Screening Level Values

For each medium, SLVs were selected for human and ecological receptors, based on a hierarchy of sources (Appendix J, Tables J-1 through J-3). Site-specific reference concentrations were used to establish SLVs for inorganic analytes in soil and sediment, only. The SLV selection hierarchy was developed based on discussions with the USACE and DEQ during the meetings held from December to February, 2010, as documented in DSR Meeting Minutes Memorandum (URS 2010a) and River OU and Upland OU DSR Response to Comments (RTC) (URS 2010b,c). Appendix J presents the agreed-upon hierarchy of Human Health and Ecological SLVs. Tables J-4 and J-5 present the SLVs for specific human health and ecological receptors, respectively, used to identify COPCs in the HHRA (Appendix M) and CPECs in the ERA (Appendix N). Appendix also presents the SLVs (generally the more conservative of the human health and ecological SLVs, unless only one is applicable) used for identifying preliminary COPCs for discussion of nature and extent of contamination (Section 9.0).

7.3.2 Identification of Bioaccumulative Compounds

In addition to selecting appropriate SLVs, bioaccumulative compounds were also identified. Bioaccumulation is a phenomenon in which concentrations of chemicals accumulate in biological tissues through exposure to environmental concentrations, which results from processes of preferential uptake and retention in adipose and organ tissues. Bioaccumulation occurs as living organisms retain and concentrate chemicals both directly from their surrounding environment (i.e., from soil or water) and indirectly from media that transfer chemicals into dietary components, such as plant or animal tissues. Biomagnification is a form of bioaccumulation in which the concentration of a chemical in a higher trophic level organism (e.g., bird, mammal, reptile, or human) is greater than the concentration in the food that this organism consumes.

Bioaccumulation and biomagnification are of primary interest in RAs because of the potential for chemical transfer through the food web, as people and top-level predatory species consume food that may have high tissue residues of bioaccumulative chemicals. Thus, even though the people or predatory biota are not directly exposed to chemicals in soil or water, they may still be adversely affected because of their indirect exposure to these chemicals through consumption of fish, shellfish, or other food items.

Hunting is prohibited on Bradford Island. Therefore, in the Upland OU only ecological receptors may be potentially exposed to bioaccumulative compounds via the consumption of prey items

that may have accumulated site COIs in their tissues. In contrast, fishing is not only allowed by commonly takes place in the River OU. Therefore, both human and ecological receptors may be potentially exposed to bioaccumulative compounds via the consumption of aquatic food items.

In support of the RAs, bioaccumulative compounds were identified for both the Upland and River OUs by examining multiple lines of evidence, as follows:

- The bioaccumulation potential of nonpolar organic compounds is generally related to their hydrophobicity or lipophilicity and is approximately estimated by their octanol-water partition coefficient (log K_{ow}). Bioaccumulative chemicals were defined as those with a log K_{ow} exceeding 3.5 (with an optimum range between 3.5 and 5.5; Suter 1993). This applies equally to organic compounds in the Upland and River OUs.
- In the River OU, inorganic compounds were identified as bioaccumulative if they had a Bioconcentration (BCF) > 300 (Suter 1993).
- In the Upland OU, inorganic compounds were identified based on bioaccumulation factors (BAFs) which are separately for earthworms, plants, or vertebrates. The Hazardous Waste Identification Rule (USEPA 1999a) recognizes compounds as having a high bioaccumulation potential if the BAF is greater than 1.0, and a medium bioaccumulation potential if the BAF is between 0.1 and 1.0. For this project, all compounds with a receptor-specific BAF > 0.1 were identified as bioaccumulative.

Compounds identified as bioaccumulative are listed in Table J-6 (Upland OU) and Table J-7 (River OU).

7.4 Data Sensitivity Analysis

In data sensitivity analysis, the goal is to evaluate the level of confidence in the low end of the reported range of concentrations with respect to its usability for the purposes of the RI. Less uncertainty is associated with the upper end of the range of reported concentrations that are well above the MDL and the MRL, i.e., well above the lowest initial calibration standard of the laboratory instrument.

Within a data set, individual data points may fall into one of three categories as they range from high to low concentrations: unqualified detections, J-flagged detections or U-flagged non-detects (Figure 7-1).

For unqualified detections, there is a high degree of confidence associated with both the identity of the analyte and its reported concentration. There is less confidence in J-flagged detections because, although the analyte has been positively identified, the reported J value is an estimated value and the true concentration may actually be as low as the MDL or as high as the MRL. The U-flagged non-detect value is understood to represent a reliable concentration limit, above which an analyte is not present.

J-flagged values represent an intermediate category of data with some associated uncertainty, in contrast to the higher level of confidence placed in unqualified detections and in U-flagged non-detects. Many analytes in the project have J-flagged data. Therefore, a data sensitivity analysis (Appendix K) was performed for analytes with a detection frequency of less than 100% (i.e., those with at least one non-detect result) and for analytes with detections below the MRL (i.e., J-flagged). The data sensitivity analysis compares the MDLs and MRLs associated with each non-

detect observation (i.e., reported below the MDL), and MRLs associated with detections below the MRL (i.e., J-flagged), with the lowest analyte-specific human health and ecological SLVs (Appendix J).

There are two objectives of this analysis:

1. The first objective is to determine whether analytes that were reported as undetected in 100% of the samples could be eliminated from any further consideration as COIs.
2. The second objective is to determine the level of confidence in the EPCs used for risk assessment (i.e., maximum concentrations or 95% UCLs) for analytes in a given medium that were not detected in all samples but were detected in at least one sample (i.e., less than 100% detection frequency, and typically greater than a 5% detection frequency).

Understanding the level of confidence in meeting these two objectives is important primarily in terms of whether the uncertainties in the data quality are likely to lead to overestimation or underestimation of risk when the data are used for risk assessment purposes. By comparing the SLVs to the MDLs and MRLs, the impact of the uncertainty regarding the J-flagged data and undetected results on the use of the data for risk assessment purposes (i.e., elimination of a COI and development of an EPC) can be evaluated.

There are three potential cases, depending on where the SLV for a given analyte falls relative to the MDL and MRL

Case 1

If the SLV is higher than both the MDL and MRL for an individual non-detect observation (Figure 7-1), then there is a high level of confidence that the analyte is not present in that sample at concentrations of potential concern. If the SLV is higher than both the MDL and MRL and 100% of the samples are non-detect for that analyte, then that analyte can be eliminated as a COI with a high level of confidence. The use of J-flagged data does not limit the ability to determine whether or not an analyte is present at a level of potential concern, because the J-flagged result is constrained to be lower than the MRL, which in turn is lower than the SLV.

Case 2

If the SLV falls between the MDL and the MRL and an individual observation is reported as a J-flagged value (Figure 7-1), some uncertainty is introduced. Pertaining to the first data use objective, if a COI is eliminated as a COPC due to comparison between a J-flagged value and the SLV, this could result in an under prediction of risk. This is because the true value of that sample may be higher than the reported J-value, up to the limit of the MRL. Under this scenario, if the J-value is actually an underestimation of the true concentration, which is higher than the SLV, the COI should really be retained as a COPC.

For the second objective, if J-flagged values are included in the estimation of the EPC, this may result in an EPC that is either an underestimate or an overestimate of the true value. This uncertainty is limited by the fact that the true value of the J-flagged data in constrained to between the MDL and the MRL. The closer the reported J-flagged value is to the MDL, the greater the potential for underestimation of risk. The closer the J-flagged

value is to the MRL, the greater the potential for overestimation of risk. Retaining the J-flagged values as detected concentrations follows accepted risk assessment protocols (USEPA 1989 et seq.) and minimizes the potential for underestimation of risk that would result from considering J-values as non-detects.

Case 3

If the SLV is lower than both the MDL and the MRL (Figure 7-1), then there is a limited ability to meet the first data use objective. U-flagged data are commonly interpreted as signifying the absence of an analyte at the MDL. If the MDL is higher than the SLV, then it is more difficult to assume that the analyte is not present at a concentration of concern and the level of confidence in eliminating the analyte is lower. Since the MDL is primarily influenced by the analytical and methodological technology, this type of uncertainty is not easily remedied unless more sensitive analytical methods are available and feasible for use.

Relative to the second objective, if J-flagged values are included in the estimation of the EPC, the same uncertainty in the calculated EPC exists as was discussed in Case 2. However, the potential exists for a greater underestimation of potential risk. This is because the upper and lower bounds of the true value of the J-flagged data remain the same (i.e., MRL and MDL), but the difference between the even lower SLV and the J-flagged value increases.

In this case (when an SLV is lower than both the MDL and MRL), the underestimation of risk related to elimination of a COI or estimation of the EPC is noted in the risk assessment and qualitatively discussed in the uncertainty section.

All three of these cases occur in the RI data set, as discussed in the sections below. The evaluation process is intentionally conservative because the lowest human health and ecological SLVs are used to evaluate data quality. In reality, multiple pathways and receptors are evaluated in the HRHA and ERA, some of which may have higher SLVs. Therefore, exceedance of the lowest SLV by the MDL or MRL does not mean that the non-detect values have the potential to overestimate or underestimate risks for all receptors and pathways, only the receptor-pathway combination with the lowest SLV. Therefore, for a given AOPC/OU, analyte, and media, if the MDL and/or MRL exceeds the lowest SLV, then the nature of the analyte and the magnitude of exceedance are further reviewed in the risk assessments to evaluate the significance of the exceedance and the possible impact on interpretation of results.

For each analyte in the entire data set, Tables K-1 to K-16 provide detailed analyses of the number of samples, lowest human health or ecological SLV, number of non-detects below the MDL (i.e., U-flagged values) and the number of detections between the MDL and the MRL (i.e., J-flagged values). The minimum and maximum MDLs and MRLs for the non-detect observations are listed, as well as the number of these MDLs and MRLs that are greater than the associated SLVs. Analytes for which a large proportion of the MDLs and MRLs for the non-detect observations exceed the SLV are associated with a higher level of uncertainty when the data are used for risk assessment purposes, as discussed above. The purpose of the tables is to allow for identification of every analyte for which some potential for underestimation or overestimation of risk may exist.

The information from Tables K-1 to K-16 is summarized in Tables 7-1 to 7-6. Data sets which have a larger degree of uncertainty, as a result of limited sample size or a high proportion of estimated data (i.e., the majority of the data is J-flagged) are summarized in Tables 7-1 and 7-2. These tables provide a summary of the detected analytes for which more than 50% of the detected concentrations consists of J-flagged results, and further highlight those analytes in the Upland and River OU data sets for which the MRL exceeded the lowest human health or ecological SLV. The inclusion of these analytes and their associated J-flagged values in the RI process indicates that there is a potential for overestimation of risk if the true value is higher than the SLV and a potential for underestimation of risk if the true value is lower than the SLV.

Table 7-3 summarizes the analytes that were never detected (100% non-detect) or sometimes detected (<100% non-detect) whose MDLs exceeded the lowest human health or ecological SLV. The elimination of the 100% non-detect analytes with elevated MDLs as COPCs is subject to an unavoidable potential for underestimation of risk since they cannot be conclusively shown to be absent at concentrations of concern. However, there is less potential for underestimation of risk related to the analytes that were sometimes detected because the estimation of the EPC for these analytes by the Kaplan-Meyer method takes the absolute value of the MDL into consideration by including these MDLs in the concentration ranking for that analyte when the UCL uses the MDL as the censoring limit.

Table 7-4 summarizes the analytes that were never detected (100% non-detect) or sometimes detected (<100% non-detect) in the Upland and River OU data sets for which either human health or ecological SLVs were not available. This represents a different type of uncertainty that is not related to analytical data quality but is relevant to the risk assessment process. The lack of SLVs indicates an absence of reliable toxicological information for the evaluation of the chemicals. Analytes that were never detected are eliminated as COPCs even if no SLVs are available and this may result in a potential for underestimation of risk. However, all analytes without SLVs (detected and non-detected) are discussed qualitatively in the Uncertainty Assessment sections of the risk assessments.

Tables 7-5 and 7-6 provide the same information as Tables 7-3 and 7-4, but for the River OU dataset.

7.4.1 Upland OU AOPCs

The following datasets were considered in the Upland OU data sensitivity analysis:

- Landfill: soil, groundwater, and seep water, and surface water
- Sandblast Area: soil, groundwater, and soil gas (human health only)
- Pistol Range: soil and groundwater (lagoon sediments were not evaluated because all of the analyzed COIs were 100% detected).
- Bulb Slope: soil

7.4.1.1 Human Health Sensitivity Analysis

Analytes with J-flagged Data with SLVs

Tables K-1, K-2, K-3, and K-4 in Attachment K present the results of the human health sensitivity analysis for the Landfill, Sandblast Area, Pistol Range, and Bulb Slope AOPCs,

respectively. As summarized in Table 7-1, more than 50% of the detected results were J-flagged for a few metals and several VOCs, SVOCs, and pesticides for the soil and water media. However, few of these analytes had MRLs that exceeded the lowest human health SLV. Thus the potential for underestimation or overestimation of risks (within the bounds of the MDL and the MRL) is limited to a few analytes (e.g., thallium and dibenz(a,h)anthracene in soil) and this uncertainty is mitigated to the extent possible by including the J-flagged data in estimating the EPCs.

Analytes with U-flagged Data with SLVs

As summarized in Table 7-3, the analytes that were never detected in upland media and also had MDLs that were higher than the lowest human health SLV included primarily several VOCs in soils, and VOCs, SVOCs and pesticides in water media. The larger number of analytes listed for groundwater is mainly due to the very low SLVs for water. Elimination of these chemicals as COPCs may have the potential to underestimate risk. Among the analytes that were sometimes detected, there are far fewer analytes whose MDLs exceed the SLVs, although again there are more exceeded analytes for water media. Use of the MDL to censor the undetected data in the EPC estimation method minimizes the potential for underestimation of risk to the extent possible.

Analytes without SLVs

As summarized in Table 7-4, analytes that were never detected in a given medium in the Upland OU and also do not have human health SLVs are primarily several VOCs in soil and water media. Elimination of these analytes as COPCs may underestimate risk, as discussed further in the Uncertainty Assessment of the HHRA. The list of analytes that were sometimes detected and do not have human health SLVs is much smaller and includes two SVOCs (n-butylbenzene and sec-butylbenzene) in soil and ethanol in soil gas. These analytes were also retained as COPCs and discussed qualitatively in the Uncertainty Assessment, as well as analytes that were detected but do not have SLVs (Section 11.0).

7.4.1.2 Ecological Sensitivity Analysis

Analytes with J-flagged Data with SLVs

Tables K-5, K-6, K-7, and K-8 in Attachment K present the results of the ecological sensitivity analysis for the Landfill, Sandblast Area, Pistol Range, and Bulb Slope AOPCs, respectively. As discussed in Section 7.4.1.1, more than 50% of the detected results were J-flagged for a few metals and several VOCs, SVOCs and pesticides for the soil and water media (Table 7-1). However, far fewer of these analytes had MRLs that exceed the lowest ecological SLV. Thus, the potential for underestimation or overestimation of risks (within the bounds of the MDL and the MRL) is limited to these analytes and the uncertainty is mitigated to the extent possible by including the J-flagged data in estimating the EPCs.

Analytes with U-flagged Data with SLVs

As summarized in Table 7-3, the analytes that were never detected in Upland soil and also had MDLs that were higher than the lowest ecological SLV primarily included one metal (antimony) several pesticides, herbicides, and VOCs, and a few SVOCs. For water, these analytes included a few dissolved metals, and several pesticides, herbicides, VOCs, and SVOCs (including PAHs). The larger number of analytes listed for groundwater is mainly due to the very low SLVs for water. Many of these non-detect analytes with MDLs above the ecological SLVs are associated

with the Landfill, due to the higher total number of samples and total number of analytes that originate from historical sampling events (older analytical methods). Elimination of these chemicals as CPECs may have the potential to underestimate risk.

Among the analytes that were sometimes detected, there are far fewer analytes whose MDLs exceed the SLV, with the exception of soils (0 to 1 and 0 to 3 feet bgs) from the Sandblast Area AOPC. Use of the MDL in the EPC estimation method minimizes the potential for underestimation of risk to the extent possible.

Analytes without SLVs

As summarized in Table 7-4, analytes that were never detected in a given medium in the Upland OU and also do not have ecological SLVs include several herbicides, VOCs, and SVOCs in soil and water media. Elimination of these analytes as CPECs may underestimate risk and is discussed further in the Uncertainty Assessment of the ERA. The list of analytes that were sometimes detected and do not have ecological SLVs is much smaller and includes TPH mixtures and one SVOC (n-butylbenzene). These analytes were retained as CPECs and discussed qualitatively in the Uncertainty Assessment of the ERA, as well as analytes that were detected but do not have SLVs (Section 12.0).

7.4.2 River OU

The following data sets were considered in the River OU data sensitivity analysis:

- Pre-Sediment Removal Forebay: sediment and clam (ecological only)
- Random Forebay: sediment, clam (ecological only), crayfish, sculpin (ecological only), large-scale sucker, and smallmouth bass
- Targeted Forebay: Eagle Creek sediment & Goose Island sediment, clam (ecological only), and crayfish
- Downstream: sediment

The major findings of the sensitivity analysis are discussed below.

7.4.2.1 Human Health Sensitivity Analysis

Analytes with J-flagged Data with SLVs

Tables K-9, K-10, K-11, and K-12 in Attachment K present the results of the human health sensitivity analysis for the Pre-Sediment Removal Forebay, Random Forebay, Targeted Forebay, and Downstream, respectively. The results are also summarized in Table 7-2. Similar to the Upland data, analytes with more than 50% J-flagged data are primarily SVOCs, TPH, a few Aroclors and a very few metals. Only a very few of these analytes, however, had SLVs that were lower than the MRLs (e.g., none in clam, Aroclor 1254 in sediment).

Analytes with U-Flagged Data with SLVs

As summarized in Table 7-5, the analytes that were never detected in River OU media and also had MDLs that were higher than the lowest human health SLV are primarily Aroclors in sediment, crayfish, large-scale sucker and smallmouth bass and a few metals in water. Although these analytes are eliminated as COPCs, PCBs are further evaluated using the more sensitive congener-based data for both COPC selection and EPC estimation. Therefore, the potential for

underestimation risk related to Aroclors is minimized. The same is true for analytes that were sometimes detected with MDLs greater than the SLVs since these are also limited primarily to Aroclors and B2EHP.

Analytes without SLVs

As summarized in Table 7-6, analytes that were never or sometimes detected in a given medium in the River OU and also do not have human health SLVs are primarily a few SVOCs such as phthalate compounds, carbazole and p-cresol. Elimination of these analytes as COPCs may underestimate risk and is discussed further in the Uncertainty Assessment of the HHRA, as well as analytes that were detected but do not have SLVs (presented in the HHRA screening tables in Section 11.0).

7.4.2.2 Ecological Sensitivity Analysis

Analytes with J-flagged Data with SLVs

Tables K-13, K-14, K-15, and K-16 in Attachment K present the results of the ecological sensitivity analysis for the Pre-Sediment Removal Forebay, Random Forebay, Targeted Forebay, and Downstream, respectively. The results are also summarized in Table 7-2. As discussed in Section 7.4.2.1, more than 50% of the detected results were J-flagged for several SVOCs, two TPH mixtures, two Aroclors (1242 and 1254) and a very few metals. Only a few of these analytes, however, had MRLs that were higher than the ecological SLVs, including a couple of PAHs and Aroclor 1254 in sediment, B2EHP in bass tissue, and dissolved cadmium in surface water.

Analytes with U-Flagged Data with SLVs

As summarized in Table 7-5, the analytes that were never detected in River OU media and also had MDLs that were higher than the lowest ecological SLVs are limited to Aroclors in sediment, clams, sculpin, and smallmouth bass. Although these analytes are eliminated as CPECs, PCBs are further evaluated using the more sensitive congener-based data for the CPEC selection process. Therefore, the potential for underestimation risk related to PCBs is minimized.

Analytes that were sometimes detected and have MDLs higher than the ecological SLV include Aroclors in sediment, clams, sculpin, and smallmouth bass (and B2EHP in bass), and dissolved cadmium and total aluminum in water. Use of the MDL in the EPC estimation method for these analytes minimizes the potential for underestimation of risk to the extent possible.

Analytes without SLVs

As summarized in Table 7-6, analytes that were never or sometimes detected in a given medium in the River OU and also do not have ecological SLVs include a few metals (antimony, beryllium, and chromium) and a couple of SVOCs (carbazole and p-cresol) in tissue, and TPH in sediment and water. Elimination of these analytes as CPECs may underestimate risk and is discussed further in the Uncertainty Assessment of the ERA, as well as analytes that were detected but do not have SLVs (Section 12.0).

7.4.3 Data Sensitivity Analysis Summary

In summary, the data quality analysis evaluated the quality of analytical data for RI use with respect to three attributes for each analyte: sample size, J-flagged data, MDLs and MRLs with respect to SLVs, and analytes without SLVs. Overall, sample sizes for each analyte are

considered to be sufficient for their intended uses since they meet the minimum required sample size for statistical evaluation or are clearly designated as targeted samples collected for non-statistical use. Eight samples is the minimum necessary to calculate a 95% UCL as the EPC, and 14 samples is the minimum desired for the population-to-population statistical comparison to identify COIs that are above Reference concentrations with the desired level of confidence. Limited sample sizes were noted for some analytes in samples intended for these statistical analyses. The maximum detected concentration was used to represent the EPC for analytes with fewer than eight samples and represents the best effort to avoid underestimation of risk. Analytes for which at least 14 samples are not available were not included in the statistical comparison, and a qualitative comparison to Reference concentrations was performed.

The use of J-flagged data and the fact that some SLVs are lower than analytical MDLs and MRLs both result in some potential for under prediction of risk but, but this uncertainty is mitigated to the extent possible by the risk assessment methodology. The treatment of analytes without SLVs may also have the potential to under predict risk, but these analytes and media are evaluated qualitatively in the risk assessments.

8.0 COMPARISON OF SITE DATA TO REFERENCE AREA DATA

This chapter, along with Appendix L, compares site data to reference area data for both the Upland and River OUs. Both organic and inorganic analytes are included. The objective is to determine which analytes measured in site media have concentrations that are elevated relative to the reference areas, and, thus, potentially attributable to the site, and which have concentrations that are indistinguishable from more widespread conditions, which are likely due to other sources not related to the site. With the exception of inorganic constituents, these results are not used for developing screening levels, or performing the screening level risk assessments.

8.1 Statistical Comparison Methods

The statistical evaluations involved the comparison of two independent data sets. In each case, statistical methods were used to compare each investigation data set to the corresponding reference data set, to determine if an analyte's concentrations were present in the site at a level significantly greater than that of the appropriate reference area. This approach is commonly known as a population-to-population comparison, and the results of this evaluation process determine whether the mean site values were statistically greater than the mean reference area values.

For this study, the hypothesis testing methods described in the USEPA guidance document *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA 2002a) and the Navy guidance document titled *Procedural Guidance for Statistically Analyzing Environmental Background Data* (Southwest Division [SWDIV] and EFA WEST 1998) were used.

Hypothesis testing refers to a category of statistical analysis methods that are used to choose between two competing statements or hypotheses. One is called the null hypothesis, denoted by H_0, and the other is called the alternative hypothesis, denoted by H_A. The null hypothesis is the baseline condition that is assumed to be true in the absence of any data. If the data provide sufficiently strong evidence contrary to the null hypothesis, the null hypothesis is rejected and the alternative hypothesis accepted. If the data do not provide sufficiently strong evidence, the null hypothesis is not rejected. However, this lack of strong evidence does not necessarily mean that the null hypothesis is true; it only means that the available data are not sufficient to prove the alternative hypothesis. If the null hypothesis is not rejected, it is important to check the power of the test, which is defined as the probability that the test would be able to detect a specified minimum true difference from the condition defined by the null hypothesis. If the power of the test is sufficiently large, and the null hypothesis is not rejected, one could say with a high degree of confidence that no change has occurred in the condition defined by the null hypothesis.

For the comparison between the site data and the reference area data, the hypothesis testing was set up as follows:

Null hypothesis, H_0: The mean concentration in the site data set was less than or equal to the mean concentration in the reference area data set.

Alternative hypothesis, H_A: The mean concentration in the site data set was greater than the mean concentration in the reference area data set.

The appropriate statistical test was selected based on the percentage of non-detects within a given pair of data sets and the distribution of the data in the data sets. If all values in both data sets for a given analyte were detects, the Shapiro-Wilk W test at a 5% significance level was used to evaluate the distributions of values in each data set (i.e., to determine if raw values or log-transformed values were normally distributed). If the data sets were neither (both) normal nor (both) lognormal, then a non-parametric Wilcoxon Rank Sum test was performed. If both data sets fitted a normal or lognormal distribution, then the Student's *t*-test was used for the evaluation. Depending on the calculated variances of the data sets for each analyte, either the form for equal variances or unequal variances was used to compare the two data sets.

If detectable values were present in at least one of the data sets, but not all concentrations were detectable, the Wilcoxon Rank Sum test was used to compute non-parametric estimates for the comparison with all non-detects censored at the median MDL/MRL (i.e., the median value of various different MDLs/MRLs for the combination of the site and reference area data sets). The effect of this censoring was to establish a minimum "cut-off" value or a common "bottom line," such that below which no data (detected or undetected) could fall, and thus a statistical comparison is plausible given the various data sets might have different censoring levels. In reviewing the population-to-population comparisons, it is important to remember that all detected data (in either the site or the reference area) which were below the cut-off value were "reset" to that cut-off value. In cases where a large percentage of detected data were reset to a higher cut-off value, the population-to-population comparison had limited power to reject the null hypothesis (i.e., to conclude the site data had a higher mean concentration than the reference area data). In these cases, other numerical or graphical tools, such as box-and-whisker plots, were used for additional evaluation.

All statistical comparisons were performed twice, once using the median MDL (of both populations combined) as the lower cut-off value for the population-to-population comparisons and once using the median MRL (of both populations combined) as the lower cut-off value. The results are presented in Appendix L. In each table, the selected test is listed under the column "Appropriate Statistical Test." A significance level (α) of 5% was used for all statistical tests, and the comparison result was presented in the form of a "Yes" or "No" answer to the question, "Is the mean Site concentration significantly higher than the mean Reference Area concentration?" If more than 90% non-detects were present in one or both data sets, the Contingency Table Analysis method was used in the evaluation, which is a comparison to determine significant differences between the detection frequencies in the site and the reference area data sets.

If the null hypothesis was not rejected (i.e., the answer was "No" to the question, "Is the mean site concentration significantly higher than the mean reference area concentration?"), a further assessment was made to evaluate the minimum detectable differences (MDDs) for which the statistical comparison could be achieved. In other words, the MDD was the minimum required "separation" between the true means of the site and reference area data for the statistical test to be able to conclude that a significant difference existed at a 95% confidence level (or false rejection rate, α=0.05) and 80% power of detection (or false acceptance rate, β=0.2).

If the null hypothesis was rejected (i.e., the answer was "Yes" to the question, "Is the mean site concentration significantly higher than the mean reference area concentration?"), there was no need to evaluate the power of the statistical comparison, because the sample data had provided evidence at the specified level of confidence that the mean site concentration was significantly

higher than the mean reference area concentration. The power analysis was not performed for data sets in which all samples were non-detects or for comparisons using the Contingency Table Analysis method.

The MDD depended on the pooled standard deviation of the reference area and AOPC data, and this pooled standard deviation. The calculation of the MDD for non-parametric tests is generally complicated. For simplicity, the calculation of the MDD was based on normal distribution theory, as an approximation, for all analytes in this evaluation. The calculated MDD was then expressed as a percentage of the mean of the reference area data. For example, if this percentage was 20%, one would interpret it as follows: if the true AOPC mean were 20% higher than the true reference area mean, the statistical test would be able to conclude that the AOPC concentrations were significantly higher, given the designed confidence level and power of detection.

The goal established in the RI/FS MP for statistical power associated with the background comparison power was achieved (i.e., to detect "one-standard-deviation-away"). However, for some Upland soils, this one-standard-deviation is high due to the high data variability, which could not be controlled because of the inherent heterogeneity of the Upland soils. As an artifact of this high data variability, MDDs greater than 100% of the reference mean were calculated for several metals in soil of the Landfill, Sandblast Area, and the four combined AOPCs (Table L-1 in Appendix L). Although the null hypothesis was not rejected, the statistical power to detect substantial differences between the site and Reference Area datasets for metals with MDDs greater than 100% of the reference mean might be limited. These metals are identified in Section 8.2.1, and the measures taken to address the uncertainty introduced in the background comparison for these metals are also described. Data variability for all metals in other datasets subjected to the statistical background comparison, i.e., sediment and tissue samples from the River, were low and the MDDs were generally well within acceptable range. The exception to this statement is lead in crayfish and chromium in bass, which are discussed in Section 8.3.1.

To address the limitation of the statistical methodology for data sets with large numbers of non-detects, all comparisons also included an examination of the data distributions using box-and-whisker plots. These plots are also included in Appendix L. For each population, the box-and-whisker plots used boxes to show the 25th percentile, median, and 75th percentile, along with whiskers extending to the outermost data point that falls within the distances computed as: (a) 25th percentile minus 1.5 times of interquartile range, and (b) 75th percentile plus 1.5 times of interquartile range. The actual data points were superimposed but jittered, with different symbols for detected and un-detected data. Examination of the box-and-whisker plots allowed for the identification of data sets in which the analyte concentrations in the site data were clearly higher than the reference area concentrations, even when the population-to-population comparisons were inconclusive.

8.2 Upland OU

The following data were collected from the Upland OU Reference Area:

- Metals and PAHs in soil (14 samples)
- Metals in groundwater (4 quarters of samples from one monitoring well)
- Organics in groundwater (1 sample from one monitoring well)

8.2.1 Soil

Reference Area soil samples were collected from the 0-1 ft bgs depth interval. The very rocky nature of the undeveloped areas of Bradford Island precluded the collection of deeper samples. However, the geologic setting and (geologically) recent formation of the island are consistent with a uniform composition of reference area soils. The population of Reference Area soil data was compared independently to soil data from each of the three depth intervals (0-1 ft bgs, 0-3 ft bgs, and 0-10 ft bgs) of each AOPC to be used in the RAs. It was recognized that the combined false positive rate for all three depth intervals was likely to be greater than 5%. However, since the decision rule was based on individual exposure area (e.g., whether a specific depth interval within a given AOPC was above or below background), a more conservative approach of using 95% confidence level (5% significance level) was used in the hypothesis testing.

Reference Area soils were analyzed for metals and PAHs (Table 6-5). There were sufficient reference soil data to perform a statistical evaluation to assess whether the mean COI concentrations in soil within each AOPC, as well as the mean soil COI concentrations for all four AOPCs combined, were significantly higher than the mean Reference Area concentrations.

Tables L-1 and L-2 (in Appendix L) present the statistical population-to-population comparison between the Reference Area data and the data from each of the Upland AOPCs, as well as the combined data set which included soil data from all four AOPCs. Figures L-1a through L-1u present the corresponding box-and-whisker plots for each of the comparisons.

For some of the metals (particularly antimony, mercury, and silver), a portion of historic Site data had elevated detection limits (both MDLs and MRLs), relative to the Reference Area data which were collected more recently. Because the median MDL or MRL was the cut-off value for both detected and undetected data, these elevated MDLs/MRLs limited the power of the statistical tests to reject the null hypothesis (i.e., to conclude the Site AOPC data had a higher mean concentration than the Reference Area data). In these cases, the box-and-whisker plots were examined and a conservative determination was made to retain some of these metals as having higher concentrations in the Site data. These metals were marked and footnoted in Table 8-1, which summarizes those analytes for which site soil concentrations were significantly higher than the Reference Area soil concentrations. This table lists analytes for which the statistical evaluations using the MDL, MRL, or both indicated significantly higher Site concentrations.

As discussed in Section 8.1, MDDs greater than 100% of the reference mean were assessed for several metals in soil of the Landfill, Sandblast Area, and the four combined AOPCs (Table L-1 in Appendix L). Although the results of the statistical background comparison indicated that concentrations of these metals were present below or equal to that of the Reference Area levels, and therefore these metals were not carried to the SLV comparison step, the high MDDs (greater than 100% of the reference mean) present an uncertainty with this finding. These metals include the following:

Landfill

- 0 to 1 foot bgs – arsenic, chromium, copper, and nickel
- 0 to 3 feet bgs – chromium, copper, magnesium, and nickel
- 0 to 10 feet bgs – arsenic, chromium, copper, magnesium

Sandblast Area

- 0 to 1 foot bgs, 0 to 3 feet bgs, and 0 to 10 feet bgs – copper, magnesium, and mercury

Four Combined AOPCs

- 0 to 1 foot bgs, 0 to 3 feet bgs, and 0 to 10 feet bgs – copper, and magnesium

To address the uncertainty with the results of the statistical background comparison, these metals were subjected to a risk-based screening evaluation in Appendix O. The purpose of this evaluation is to explore whether or not these metals should be included as COPCs, and ultimately advanced to the next level of risk assessment or directly to the FS. A weight-of-evidence approach similar to the one implemented in Sections 11 and 12 (screening level risk assessments) was used to evaluate these metals, as described in Appendix O.

With the exception of a single PAH (acenaphthylene) in the 0-1 ft bgs interval in the Landfill AOPC, the statistical comparisons concluded that all PAHs were detected at higher concentrations in Upland OU site soils than in Reference Area soils (Tables L-1 and L-2). Further examination of the single exception revealed that acenaphthylene was only detected in a single sample in the Reference Area, and thus, the Contingency Table Analysis was used in the statistical comparison. This method is less powerful to detect differences, especially when the MDLs and MRLs were quite different for the two data sets. Examination of the box-and-whisker plots for this analyte confirmed that there was not sufficient data to conclude that the concentrations were not statistically higher in the site data. No other organic compounds were analyzed for in the Reference Area soils.

8.2.2 Groundwater and Seep Water

There were insufficient groundwater data to perform statistical comparisons between the Site and Reference Area data. Therefore the groundwater data were evaluated by comparing the range of analyte concentrations observed in groundwater samples from monitoring wells in the Landfill and Sandblast Area AOPCs with the range of concentrations observed in the Reference Area monitoring well (MW-10).

Table L-3 shows the results of this comparison. The table also lists the range of concentrations observed in the seep samples collected along the perimeter of the Landfill AOPC, and compares those with concentrations observed in the Reference Area monitoring well. Not all analytes were measured in the Reference Area monitoring well. For those analytes that were measured, groundwater concentrations at the AOPCs, appeared to exceed Reference Area groundwater concentrations for most COIs. The results are summarized in Table 8-2.

At the Landfill AOPC, COI concentrations in seep water were generally lower than concentrations observed in groundwater, and fewer analytes exceeded the corresponding Reference Area groundwater concentrations. Arsenic, barium, copper, iron, lead, mercury, selenium, diesel range organics (DRO), residual range organics (RRO), chloroform and PCE were the only analytes for which seep water concentrations exceeded Reference Area concentrations (Table 8-2).

8.3 River OU

The following data were collected from the River OU Reference Area:

- Metals and organics in sediment (18 samples)
- Metals and organics in clams (18 samples)
- Metals and organics in crayfish (19 samples, except SVOCs which only have 18 samples)
- Selected metals and PCBs in sculpin (18 samples)
- Metals and organics in smallmouth bass (19 samples)
- Metals and organics in surface water (5 samples)

These data were compared to the random Forebay data sets, the targeted Forebay samples, and the Downstream sediment samples. In addition, soils potentially subject to mass wasting or erosion from the Upland OU (in the Landfill, Sandblast Area, and Bulb Slope AOPCs) may be transported to the River OU. Therefore, these soils were compared to both Upland Reference Area soil data and River Reference Area sediment data to evaluate the potential for these Upland OU soils to impact the River OU should they be transported into the river.

8.3.1 Forebay Random Samples

By design, sufficient sediment, clam, crayfish, sculpin, and smallmouth bass samples were collected from the upstream Reference Area to allow for a robust statistical comparison to the Forebay random data sets. The Reference Area samples were analyzed for the same suite of analytes as the Forebay samples.

Tables L-4 and L-5 (in Appendix L) present the statistical population-to-population comparisons between the Forebay random data set and the Reference Area data set for the sediment and tissue non-congener data. As with the Upland OU data, the statistical comparisons were performed twice, once censoring non-detect data at the median MDL and once censoring the non-detect data at the median MRL. Table L-6 presents the statistical population-to-population comparisons for the congener data. Since MDLs and MRLs are not available for the congener data, the statistical comparisons were performed only once, with non-detect data censored at the RDL and the EMPC-qualified data censored at the full reported value. Figures L-2 through L-6 present box-and-whisker plots for each of the statistical comparisons, for sediment, clams, crayfish, sculpin, and smallmouth bass, respectively.

The population-to-population comparisons were not conducted for every congener. Instead, the comparisons were carried out for the twelve dioxin-like congeners, and for the sum of 209 congeners. If concentrations of any of the dioxin-like congeners were found to be significantly higher in the Forebay, then concentrations of any of the other individual congeners which were not evaluated could be considered potentially higher in the Forebay. The statistical comparison of total PCBs (as sum of 209 congeners) was conducted separately, and the calculation of the sum of 209 congeners was based on the K-M method.

Table 8-3 summarizes those analytes for which Forebay sediment and tissue concentrations were significantly higher than the Reference Area concentrations. Censoring non-detect data at the MRLs (rather than the lower MDLs) generally reduced the ability of the statistical test to differentiate between the Forebay and the Reference Area data sets, and rendered it more likely that the test would conclude that concentrations in the Forebay were not significantly higher than that in the Reference Area. Therefore, the conservative approach was taken, and analytes were

listed in Table 8-3 even if only the MDL-censored data set led to the conclusion that the Forebay concentrations were significantly higher.

As discussed in Section 8.1, MDDs greater than 100% of the reference mean were assessed for lead in crayfish and chromium in bass (Table L-4 in Appendix L). Although the results of the statistical background comparison indicated that concentrations of these metals were present below or equal to that of the Reference Area levels, and therefore these metals were not carried to SLV comparison step, the high MDDs (greater than 100% of the reference mean) present an uncertainty with this finding. To address this uncertainty, lead in crayfish and chromium in bass were subjected to a risk-based screening evaluation in Appendix O. The purpose of this evaluation is to explore whether or not these metals should be included as COPCs, and ultimately advanced to the next level of risk assessment or directly to the FS. A weight-of-evidence approach similar to the one implemented in Sections 11 and 12 (screening level risk assessments) was used to evaluate these metals, as described in Appendix O.

There were insufficient surface water samples to perform statistical comparisons between the Forebay and Reference Area data. Therefore box-and-whisker plots were used to compare the surface water total concentrations (unfiltered grab samples and the sum of filter plus column for XAD samples) from the Forebay with those observed in the Reference Area. These results are presented in Figures L-7a through L-7f. Table 8-4 summarizes those analytes for which Forebay total surface water concentrations appeared to be higher than Reference Area total surface water concentrations, based on the available data set.

Each of the Forebay media are discussed individually, below.

Sediment

Population-to-population statistical comparisons showed that for all metals, concentrations observed in the 19 random Forebay sediment samples were not significantly higher than the concentrations observed in the 18 random Reference Area samples (Table 8-3). Similarly, none of the PAHs had sediment concentrations which were significantly higher in the Forebay than in the Reference Area. Neither DRO, nor Aroclor 1254 (the only Aroclor detected) concentrations were significantly higher in the Forebay than in the Reference Area. The only compounds which were shown to be higher in the Forebay, with a statistically significant level of confidence were RRO and several of the dioxin-like congeners. Interestingly, the concentration of total PCBs (as congeners) was not significantly higher in the Forebay than in the Reference Area (Table 8-3 and Figures L-2a through L-2g). These conclusions were identical, whether the non-detect data were censored at the MDLs (Table L-4) or the MRLs (Table L-5).

Clams

The results of population-to-population statistical comparisons between the random Forebay and Reference Area clam data are summarized in Table 8-3. In clams, beryllium and cadmium were the only inorganic analytes for which random Forebay concentrations were significantly higher than Reference Area concentrations. Among the organics, concentrations of acenaphthene, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, pyrene, and selected dioxin-like congeners were also significantly higher in the Forebay. Concentration of total PCBs (as congeners) in clam tissue was not significantly higher in the Forebay than in the Reference Area (Table 8-3). The only difference in the conclusions when the population-to-population comparisons censored non-detect data at the MRLs, versus the MDLs, was that beryllium was no longer significantly higher

in the Forebay clam when the MRLs were used for censoring (compare Tables L-4 and L-5 and Figures L-3a through L-3g).

Crayfish

In crayfish, antimony, arsenic, chromium, mercury, methyl mercury, and nickel concentrations were significantly higher in the random Forebay samples than the River Reference Area samples, whether the undetected results were censored at the MDLs or the MRLs (Tables L-4 and L-5). Among PAHs, acenaphthene, benzo(a)anthracene, benzo(g,h,i)perylene, fluoranthene, phenanthrene, and pyrene were found to be significantly higher in the Forebay when the MDLs were used to censor the non-detect data. When MRL-censoring was used, the ability of the statistical test to differentiate between the Forebay and Reference Area populations was significantly reduced (compare Tables L-4 and L-5 and Figures L-4a through L-4g). Concentrations of individual dioxin-like congeners, as well as total PCBs (as congeners) were significantly higher in the Forebay crayfish than in the Reference Area crayfish. These results are summarized on Table 8-3.

Sculpin

Due to insufficient sample volumes, the sculpin were only analyzed for four metals and PCBs. Among those metals analyzed, cadmium, lead, and mercury concentrations were significantly higher in the Forebay sculpin than in the Reference Area sculpin (Table 8-2 and Figure L-5a). Aroclor 1254 (the only Aroclor detected) concentrations were no higher in the Forebay than in the Reference Area, but the power of this conclusion was limited by the fact that Aroclors were detected in only a few samples (Tables L-4 and L-5 and Figures L-5b). In contrast, when the more sensitive PCB congener analysis was used and the detection rate increased, the population-to-population statistical tests had sufficient power to conclude that concentrations of individual dioxin-like congeners, as well as total PCBs (as congeners) were significantly higher in the Forebay than in the Reference Area (Table L-6, and Figure L-5c). These conclusions were identical, whether the non-detect data were censored at the MDLs (Table L-4) or the MRLs (Table L-5).

Smallmouth Bass

The results of population-to-population statistical comparisons between the random Forebay and River Reference Area smallmouth bass data are also summarized in Table 8-3; the box-and-whisker plots are provided in Figures L-6a through L-6g. For smallmouth bass, aluminum, barium, copper, mercury, and zinc concentrations were significantly higher in the random Forebay than the Reference Area. Anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and pyrene were found to be significantly higher in the Forebay when the MDLs were used to censor the non-detect data. Aroclors 1242 and 1254 were detected, but the limited number of detections resulted in the conclusion that the Forebay concentrations were no higher than the Reference Area concentrations (Tables L-4 and L-5). An examination of the box-and-whisker plots (Figures L-6e) revealed that Aroclor concentrations were higher in the Forebay smallmouth bass. This was confirmed with the more robust data set afforded by the congener analysis. Concentrations of all of the dioxin-like congeners, as well as total PCBs (as congeners), were significantly higher in the Forebay than the Reference Area (Table L-6 and Figure L-6f). Additionally, B2EHP was found to have statistically higher concentrations in Forebay smallmouth bass than in Reference Area smallmouth bass – although there was no statistical

difference found for this analyte in any of the other media (Table 8-3). These conclusions were identical, whether the non-detect data is censored at the MDLs (Table L-4) or the MRLs (Table L-5).

Surface Water

The sample size (five each in the Forebay and Reference Area) was too small for statistical comparison, so the surface water was evaluated semi-quantitatively using box-and-whisker plots (Figures L-8a through L-8g). This analysis was performed using the total surface water concentrations (as opposed to dissolved). The results are summarized in Table 8-4.

Among the metals, the range of concentrations detected in Forebay surface water were less than the range detected in Reference Area surface water, with the exception of aluminum and barium (Figure L-7a). For each of these COIs, the detected concentration in one Forebay sample was higher than the maximum concentration detected in the Reference Area. Among the organic analytes, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, phenanthrene, a few of the dioxin-like PCB congeners, and total PCBs (and congeners) also had maximum detected Forebay concentrations which exceed the maximum Reference Area concentrations. In all cases, the magnitude of these exceedances were small, making it hard to conclusively state that concentrations of these analytes are higher in the Forebay. However, to be conservative, all are listed on Table 8-4.

8.3.2 Forebay Targeted Samples

Since the sample size for the targeted areas of the Forebay (Eagle Creek and Goose Island) were too small to allow for statistical comparisons to Reference Area samples, the concentrations observed in these targeted samples were compared to Reference Area concentrations by evaluating whether or not the concentrations observed in the targeted samples were within the range of concentrations observed in the same media in the Reference Area, and whether they fell below the 95% UPL of the reference area data. The results are presented in Table L-7, and discussed below.

Eagle Creek

The mouth of Eagle Creek was represented by only two sediment samples. Concentrations of all metals, TPHs, and phthalates were less than the range of concentrations observed in Reference area sediments. Aroclor 1248 was detected in one sample (which exceeded the undetected results from the Reference Area); congeners were not analyzed. In addition, the concentration of carbazole, anthracene, phenanthrene, chrysene, and total LPAHs exceeded the Reference Area concentrations, but only in the sample that contained Aroclor 1248 (Table L-7).

Goose Island

The Goose Island targeted samples include two sediment samples and one sample each of clam, crayfish, and sculpin. Among the metals, concentrations of antimony, cadmium, thallium, and zinc were higher in the Goose Island sediments than in Reference Area sediments. However, this was not true for the tissues. The clam sample only had one metal (beryllium) with a concentration higher than Reference Area concentrations; the crayfish sample had a higher concentration of mercury than Reference Area concentrations, and no metals were higher in the sculpin. This does not suggest a local source of metals, but instead may be indicative of natural variability.

Regarding organic analytes, concentrations of DRO, RRO, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, Aroclor 1260, selected dioxin-like PCB congeners, and total PCBs exceeded Reference Area concentrations in one or both of the sediment samples. However, in tissue, only a few PAHs were higher in the Goose Island samples than in the Reference Area. Most significantly, none of the individual PCB Aroclors or dioxin-like congeners, and none of the total PCBs (calculated as either Aroclors or congeners) had concentrations exceeding Reference Area concentrations in any of the tissues (clams, crayfish, or sculpin) (Table L-7). Again, this does not suggest a local contamination source, but may instead reflect natural variability.

8.3.3 Downstream Sediments

The objective of the downstream sampling was to determine whether or not contaminated sediments from the Forebay may have migrated and accumulated in the Downstream area and whether further sampling might be needed to assess the potential contamination.

Unlike the Forebay and Reference areas, a non-statistical sampling approach was implemented Downstream, whereby areas of the river most conducive to sedimentation were targeted for sampling (depositional areas identified by lower river velocities) in an attempt to collect from locations most likely to be impacted by Forebay sediment transport. During the post-removal in-water sampling that occurred in March 2008, sediment was collected from six Downstream locations. These samples were collected from 1,200 feet below the dam to approximately 26,500 feet (5.0 miles) downstream of the dam.

All Downstream sediment samples were analyzed for the same chemicals that were analyzed in the Forebay and Reference areas: SVOCs (including PAHs), metals, PCBs as Aroclors, TPH, and sediment quality parameters (i.e., total organic compounds [TOC] and grain size).

COI concentrations in the downstream sediment samples were compared to concentrations in Reference Area sediments to determine whether or not site-related contamination may be present downstream of the Forebay. The sample size (six samples) is too small for statistical comparison, so the population of downstream samples were compared to the reference area population using box-and-whisker plots. The results are presented in Figures L-8a through L-8g (Appendix L).

For all analyte groups, the downstream sediments concentrations appeared to be essentially indistinguishable from the Reference Area concentrations. There were a few cases where a single concentration measurement in a downstream sample might be higher than the maximum concentration measured in the Reference Area, but the overall distributions appeared to be comparable.

See Section 9.6.1, which provides an evaluation of the Downstream sediment.

8.3.4 Upland OU Soils that may be Transported to the River OU

As described in Section 4.3, the soils on the steep slopes of the Landfill and Bulb Slope AOPCs may be subject to mass wasting in which the soils would be transported to the River OU. In addition, the surface soils in a small portion of the Sandblast Area AOPC were temporarily erodible, as a result of construction activities at the AOPC in 2009. Therefore the concentrations in these erodible/mass wasting soils were compared to sediment concentrations in the River OU

Reference Area to determine whether or not the soil concentrations are significantly higher than the Reference Area sediment concentrations. This was accomplished by comparing the maximum concentration observed in the erodible soil samples to the maximum and 95% UPL of the Reference Area sediment samples (Table L-8). In general, analyte concentrations were higher in these soils than in the Reference Area sediments. The only exceptions were aluminum, antimony, barium, beryllium, and vanadium.

These erodible/mass wasting soils were also compared to Reference Area soils from the Upland OU, again by comparing the maximum concentration observed in the erodible soil samples to the maximum and 95% UPL (Table L-9). Again, the analyte concentrations were generally higher in these soils than in the Reference Area sediments. The only exceptions were aluminum, beryllium, and manganese.

9.0 NATURE AND EXTENT OF CONTAMINATION

This section describes the nature and extent of contamination associated with releases at the Bradford Island Upland and River OUs. The AOPC boundaries for each of the Upland AOPCs were developed based on historical knowledge of usage, physical parameters (e.g., the river), and site observations and investigations, including geophysical surveys of the Landfill AOPC. This section focuses on the preliminary COPCs that were identified within each AOPC or the River OU (see Section 9.1), which are potentially associated with an unacceptable risk to human and/or ecological receptors. The following essential nutrients were excluded as potential COPCs or CPECs in soil and sediment: calcium, iron, magnesium, potassium, and sodium. However, these essential nutrients were evaluated for groundwater, seep water, and surface water.

Constituents that were undetected in all samples of a given media were not evaluated in this section of the report. Instead, these undetected constituents are addressed in the data sensitivity analysis (see Section 7.4 and Appendix K). COIs that lacked SLVs are not discussed herein, but are addressed in the uncertainty sections of the HHRA and ERA.

This section includes a number of figures showing the spatial distribution of preliminary COPCs in various media. The station symbols and preliminary COPC concentrations shown in the associated text boxes have been colored to indicate whether the concentration is above the most conservative SLV (red), less than the SLV (green), undetected (black), or not analyzed (grey). Surface (0-1 foot bgs) and shallow soil (0-3 feet bgs) data were plotted together because both of these depth intervals were screened against the lower of the ecological and human health SLVs. Deeper soil (> 3 feet bgs) data were plotted on separate figures because they were only screened against human health SLVs (this soil interval is not ecologically relevant for assessment; (URS 2007a). However, during the HHRA, data from the entire depth interval (0-10 feet bgs) was evaluated for risk to human receptors.

Throughout this section, please note that PAHs are discussed separately from other SVOCs.

9.1 Identification of Preliminary COPCs

Consistent with DEQ and USEPA guidance, COIs are chemicals that are known to be present or may be present at a site (DEQ 2000; USEPA 1989, 1997a,b, and 1998). The COIs identified in environmental media in the Upland and River OUs were subjected to a multi-step screening process to identify those chemicals potentially associated with an unacceptable risk to human and/or ecological receptors, hereafter termed “preliminary COPCs.”

The multi-step screening process included an evaluation of detection frequency, comparison to background levels for inorganics, and a preliminary screening in which COI concentrations were compared against the lowest potentially-applicable SLV for human and/or ecological receptors. The nature and extent of contamination and the fate and transport of these preliminary COPCs are discussed herein and in Section 10. The final selection of COPCs and CPECs, including an evaluation of receptor specific toxicity and multiple COI toxicity, is completed in the HHRA (see Section 11 and Appendix M) and ERA (see Section 12 and Appendix N).

Relevant media, depth intervals, and EPCs for specific human and ecological receptors are discussed in the Upland and River DSRs (URS 2009d,e), DSR Meeting Minutes Memorandum (URS 2010a), River OU and Upland OU DSR RTC (URS 2010b,c), and the Area-Weighted Average Memorandum (URS 2010d). Additional information regarding relevant media and

depth intervals for specific human health and ecological receptors is included in the HHRA (see Section 10 and Appendix I) and ERA (see Sections 11 and Appendix J). Please note that the preliminary COI screening utilizes the maximum detected concentration for the EPC, which is compared to the lowest of the human health and ecological SLVs, since the most conservative screening approach was desired at this point in the process.

The preliminary COI screening methodology utilized to identify the preliminary COPCs is similar to the methodology presented in the RI/FS MP (URS 2007a) and screening conducted in the Upland and OU DSRs (URS 2009d,e). However, this RI screening supersedes the DSR screenings because the data set is different (additional data are included in this RI report) and the SLVs have since been revised. The preliminary COI screening process steps vary depending on the OU, media, and contaminant group, as discussed below.

Section 8.0 compared inorganic soil, sediment, and tissue data from the Upland and River Reference Areas with site concentrations to differentiate site-related concentrations of inorganic COIs from are naturally occurring concentrations. A population-to-population statistical comparison for the Upland OU organic data was also performed by comparing the soil PAH concentrations within each AOPC and for all four AOPC combined to the Reference Area PAH concentrations. Similarly, a population-to-population statistical comparisons for organic data between the Forebay and Reference Areas of the River OU was performed. However, the results of these organic statistical comparisons were not used for the preliminary COPC identification or the identification of COPCs and CPECs in the risk assessments and are not discussed in this nature and extent of contamination section or the fate and transport section (Section 9.0). The results of the organic statistical comparisons are discussed in Section 8.0 and Appendix L.

9.1.1 Upland OU

The Upland OU data set evaluated in this section includes the historical and recent soil, lagoon sediment, groundwater, seep water and adjacent surface water, and/or soil gas from within each AOPC (see Tables 5-1 through 5-7 and Tables 6-2 through 6-4). For the Pistol Range and Bulb Slope AOPCs soil evaluations, only surface soil was evaluated (0 to 1.5 feet bgs and 0 to 1 foot bgs, respectively). As noted in the RI/FS MP, a review of historical activities and the source of contamination at the Pistol Range AOPC (bullets and casings from firing practice) are consistent only with surface impacts; therefore, deeper samples do not need to be evaluated for this AOPC. Since the Bulb Slope AOPC only has a thin layer of soil underlain by a bedrock base, there are no soils deeper than 1 feet bgs in this area and the existing surface soil data are sufficient to evaluate risk.

Each media was screened against the media-specific SLVs described above. In addition, selected soil samples were also screened against sediment SLVs as follows:

- While there is no visual evidence of current sloughing or erosion at the Landfill AOPC and minimal visual evidence of potential sloughing at the Bulb Slope AOPC, sloughing of soils from the steep slopes on the northern side of Bradford Island is possible. Therefore, all soil results in the Bulb Slope AOPC and those surface soil samples collected from the steep slope on the northern edge of the Landfill AOPC (BIL01USE through BIL09USE, BIL13SSI, and L-01 through L-04) were also screened against sediment SLVs.

- The erodibility assessment (Appendix E of URS 2009f) determined that there was the potential for soil to be eroded from a portion of the Sandblast Area AOPC and transported to the river that had been disturbed during construction activities. The subset of soil samples within the erodible area (SB-EUA, SB-EUB, SB-EUA-02, SB-EUA-04, SB-EUA-06, SB-EUA-08, SB-EUB-02, SB-EUB-03, SB-EUB-12, SB-EUB-15, and SB-04) was screened against sediment SLVs. Please note that this area has become revegetated during the past year and is no longer considered to be erodible (see Section 4.1.3).

Soil

1. *Frequency* – Within each AOPC and for all four AOPCs combined, COIs were not retained as preliminary COPCs if detected at a frequency of 5% or less with a sample size of 20 or more (Appendix I, Tables I-1 through I-5).

   Statistical Comparison Between the Reference Area and AOPCs for Inorganics Only – In Chapter 8, a statistical comparison of two independent data sets was performed between the Reference Area surface soil data set (Appendix I, Table I-6) and each of the Upland AOPC soil data sets (for each of the depth intervals; 0-1, 0-3, and/or 0-10 feet bgs). In addition, the comparison to Reference Area soils was performed for the combined data sets (including all four Upland AOPCs) for each depth interval.

   Inorganic COIs were not retained as preliminary COPCs within a given AOPC or for all four AOPCs combined if the statistical comparison indicated that the AOPC data were not significantly greater than the Reference Area data (Table 8-1 and Appendix L, Tables L-2 and L-3).

2. *SLV Screening* – COIs within each AOPC and for all four AOPCs combined were not retained as preliminary COPCs if they were detected at concentrations below the soil SLVs (Tables 9-1 through 9-5).

Potentially Erodible or Mass Wasting Soils

1. *Comparison to Reference Area Sediments for Inorganics Only* – Since the erodible soils (from 2009) and soils potentially susceptible to mass wasting may impact river media if the soils are transported to the river, the inorganic data were compared to Reference Area sediment data from the River OU. The objective of this comparison was to determine if the inorganic COI concentrations were elevated above the naturally occurring concentrations in the river (i.e., the Reference Area sediment concentrations) (Appendix L, Table L-8).

2. *SLV Screening* – COIs detected in the potentially erodible or mass wasting soil within the were not retained as preliminary COPCs for the erodibility and mass wasting pathway if they were detected at concentrations below the sediment SLVs (Table 9-6).

Lagoon Sediment

1. *Comparison to Reference Area Sediments for Inorganics Only* – The inorganic data from the Pistol Range AOPC lagoon sediments were compared to Reference Area sediment data from the River OU to determine if the concentrations were elevated above the naturally occurring concentrations in the river.

2. *SLV Screening* – COIs detected in the Pistol Range AOPC lagoon sediment were not retained as preliminary COPCs if they were detected at concentrations below the sediment SLVs (Table 9-3).

Groundwater, Seeps, and/or Surface Water

1. *Frequency* – Within each AOPC and for all four AOPCs combined, COIs were not retained if detected at a frequency of 5% or less with a sample size of 20 or more (Appendix I, Tables I-1 through I-5).
2. *Reference Area Groundwater Comparison for Inorganics Only* - For groundwater, the inorganic groundwater data for COIs within each AOPC and all four AOPCs combined were compared to the Reference Area groundwater data. The objective of this comparison was to determine if Upland OU inorganic COI concentrations were elevated above the site-specific naturally occurring levels (i.e., the Reference Area groundwater concentrations) (Table 8-2 and Appendix L, Table L-3). Inorganic COIs within each AOPC and within all four AOPCs combined were not retained as preliminary COPCs if they were detected at concentrations at or below the Reference Area groundwater data.
3. *SLV Screening* – Those COIs that were retained after step 2 (i.e., COIs with > 5% detections and concentrations > reference area concentrations) were then compared to the water SLVs. COIs within each AOPC and within all four AOPCs combined were not retained as preliminary COPCs if they were detected at concentrations below the water SLVs (Tables 9-1 through 9-5).

Soil Gas

1. *SLV Screening* – VOCs within the Sandblast AOPC were not retained as preliminary human health COPCs if they were detected at concentrations below the SLVs (Table 9-2).

Summary

Those Upland COIs not eliminated during the preliminary COI screening process were retained as preliminary COPCs and are summarized in Table 9-7. The nature and extent of preliminary COPC contamination at each AOPC within the Upland OU are presented in Sections 9.2 through 9.5. In addition, all potentially bioaccumulative COIs, which have a BAF > 0.1 or log K_{ow} > 3.5, detected in the Upland OU were further evaluated in the ERA. The Upland OU detected bioaccumulative COIs are listed in Appendix J, Table J-6.

9.1.2 River OU

Forebay Random Samples

The Forebay data set of samples from the randomly selected locations evaluated in this section includes the post-removal surface water, sediment, and tissue, as well as the pre-removal 2006 smallmouth bass. This data set does not include the Eagle Creek, Goose Island, Downstream, or pre-removal sediment and clam data sets, which were evaluated separately. The following summarizes the preliminary COI screening process for the random Forebay data set:

1. *Frequency* – COIs were not retained as preliminary COPCs if detected at a frequency of 5% or less with a sample size of 20 or more (Appendix I, Tables I-8a and I-8b).

   Statistical Comparison to Reference Area for Inorganics Only – Similar to the Upland OU, Chapter 8 included a statistical (population-to-population) comparison of two independent data sets for each media was performed between the Reference Area sediment and tissues (clam, crayfish, smallmouth bass, and sculpin) and the random Forebay sediment and tissues. Inorganic COIs were not retained as preliminary COPCs within the Forebay if the statistical comparison indicated that the Forebay data were not significantly greater than the Reference Area data (Tables 8-3 and 8-4; Appendix L, Tables L-4 through L-6).

2. *SLV Screening* – COIs were not retained as preliminary COPCs within the Forebay if they were detected at concentrations below their media-specific (i.e., water, sediment, and tissue) SLVs (Table 9-8).

Forebay Targeted Samples - Goose Island and Eagle Creek

1. *Comparison to Reference Area for Inorganics Only* – For the targeted Forebay sampling locations at Goose Island and Eagle Creek, which do not have enough samples to perform a statistical (population-to-population) comparison, the maximum detected inorganic concentrations in sediment and tissue (clam and crayfish) were compared to the inorganic in the Reference Area data (Appendix L, Table L-7). COIs were not retained as preliminary COPCs if detected at concentrations less than the Reference Area.

2. *SLV Screening* –COIs were not retained as preliminary COPCs at Goose Island or Eagle Creek if they were detected at concentrations below their media-specific (i.e., water, sediment, and tissue) SLVs (Tables 9-9 and 9-10, respectively).

Summary

Those River COIs not eliminated during the preliminary COI screening process were retained as preliminary COPCs and are summarized in Table 9-11. The nature and extent of preliminary COPC contamination within the River OU are presented in Section 9.6. In addition, all potentially bioaccumulative COIs, which have a BCF > 300 or log K_{ow} > 3.5, detected in the River OU were further evaluated in the HHRA and ERA. The River OU detected bioaccumulative COIs are listed in Appendix J, Table J-7.

9.2 Landfill AOPC Nature and Extent of Contamination

As previously described, the Landfill AOPC was used by the USACE to manage, store, and dispose of waste materials from approximately 1942 to 1982, with its heaviest use in 1952. The Landfill AOPC encompasses approximately 28,000 square feet on the northeast corner of Bradford Island (Figure 3-3). Based on a review of aerial photographs, the Landfill AOPC was capped by 1982. In 1989, an additional soil cover (approximately 8 inches thick) was placed on the Landfill site by the USACE and the site was managed as a wildlife habitat for geese (Hibbs, personnel comm. 2001). Although this portion of Bradford Island is managed as wildlife for geese (USACE 1997a), active management (periodic mowing) of the habitat ceased in the middle to late 1990s to prevent geese from laying eggs in areas that are under investigation (Hibbs, personnel comm. 2001).

The surface of the actual Landfill (excluding the steep slopes around the perimeter of the AOPC) slopes gently to the northwest, north, and northeast, toward the Columbia River. The Landfill road runs along the southern margin of the Landfill. The Landfill surface is densely vegetated with forest, scrub-shrub, and herbaceous vegetation. The road is more sparsely vegetated with herbaceous vegetation. No evidence of runoff or erosion was observed or predicted through modeling for the Landfill surface (URS 2009f). Minor runoff has been observed on the Landfill road. The source of the Landfill road runoff is a groundwater seep at the base of the steep slope along the southern margin of the Landfill. The water flows west along the road and then infiltrates along the northern margin of the Landfill road to the west of the Landfill. The runoff water was clear at the time of the field survey, indicating that the flow of seep water along the road is not causing soil erosion. Runoff from the road appeared to infiltrate and evidence of direct discharge of road runoff to the river was not observed (URS 2009f).

While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, undercutting was observed along the waterline at the north slope indicating that historical mass wasting may have occurred. Although the potential for bedrock failure is low, if mass wasting were to occur on the steep slopes, the soils may reach the river.

Shallow groundwater flows to the north and enters the river through bottom sediments or above-water surface seeps. During the wet season, groundwater may rise shallow enough to encounter waste materials in a small portion of Landfill AOPC.

9.2.1 Soil

There have been extensive investigations of the surface/shallow soil across the Landfill AOPC, including the collection of 37 surface and shallow samples. Deeper soil samples are limited to 18 locations within two areas: the gully test pit and the mercury vapor-lamp test pit (see Figure 5-2). Soil analytical results are present on Tables 5-1a through 5-1c, 5-2a through 5-2d, 5-3a and 5-3b, and 6-2a. Appendix I, Table I-1 presents the summary statistics and detection frequency for the Landfill AOPC data.

Metals

Metals were detected in surface, shallow, and deeper soil throughout the Landfill AOPC. Concentrations of several metals (antimony, arsenic, cadmium, lead, mercury, and/or zinc) exceeded soil SLVs at most surface/shallow soil locations (Figure 9-1a). Concentrations of these metals in deeper soil are comparable to concentrations in surface/shallow soils (Figure 9-1b). However, there are only a few locations at which any of these metals (arsenic and/or lead) exceeded the less conservative human health soil SLVs that are applicable to the deeper interval.

It is also important to note that the concentrations of arsenic observed in Landfill soils are no higher (based on statistical population-to-population tests) than site-specific reference area soils (see Table 8-1 and discussion in Section 8.1). Therefore, although soil arsenic concentrations may exceed conservative SLVs, the source of the arsenic is naturally-occurring and unrelated to site activities.

Butyltins

Butyltin analyses were conducted at 22 surface, shallow, or deep sample locations, and detected in one surface, one shallow, and two deep locations. None of the butyltin concentrations exceeded their soil SLVs in surface, shallow, or deeper soil (see Table 9-1).

Herbicides & Pesticides

Herbicides were detected in a few surface and shallow sample locations across the Landfill AOPC but not in deeper soil. Pesticides were detected in several surface and shallow sample locations and a few deeper locations. Concentrations of several herbicides and pesticides (2,4,5-T, dichloroprop, MCPP, and 4,4'-DDT) only exceeded soil SLVs at a few surface/shallow soil locations, scattered across the Landfill AOPC (Figure 9-1c). In deeper soil, pesticide concentrations were lower than both less conservative deeper soil SLVs and the more conservative surface and shallow soil SLVs (see Table 9-1 and Appendix I, Table I-1).

PCBs

PCBs were detected in the majority of the surface, shallow, and deeper sample locations throughout the Landfill AOPC. However, concentrations of total PCBs (as Aroclors) exceeded soil SLVs at only three surface/shallow soil locations, all in the western portion of the Landfill AOPC (Figure 9-1d). In deeper soil, the only location where the total PCB (as Aroclors) concentration exceeded the less conservative human health soil SLV, applicable to the deeper interval, was at the gully test pit sample location BIL01TPG (which is treated as both a surface/shallow sample and deeper sample because it is unknown where it occurs in the 0-10 feet interval) (Figure 9-1e).

PAHs

PAHs were detected in all surface, shallow, and deeper sample locations except shallow location BIL13SSI. Total HPAH concentrations exceeded the soil SLV at most surface/shallow soil locations (Figure 9-1f). There is no soil SLV applicable to total HPAHs in the deeper soils. However, concentrations of most of the individual HPAHs exceeded their less conservative human health soil SLVs at most deeper locations (see Table 9-1). Total LPAH concentrations only exceeded soil SLVs at one shallow location at the gully test pit (BIL18) (Figure 9-1f). There is no soil SLV applicable to total LPAHs in the deeper soils. None of the individual LPAHs exceeded their less conservative human health soil SLVS applicable to the deeper interval (see Table 9-1).

TPH

TPHs were detected in the majority of the surface, shallow, and deeper soil samples throughout the Landfill AOPC. Concentrations of GRO exceeded the soil SLV at only a single surface/shallow soil location, within the mercury vapor-lamp test pit (BIL29TPM) (Figure 9-1g). Concentrations of DRO and RRO did not exceed their soil SLVs at any of the surface/shallow soil locations. In deeper soil, with the exception of BIL29TPM (which is treated as both a surface/shallow sample and deeper sample because it is unknown where it occurs in the 0-10 feet interval), no deeper soil locations with DRO, GRO, or RRO concentrations exceeded their soil SLVs (Figure 9-1h).

SVOCs

In addition to PAHs, other SVOCs were detected in the majority of the surface, shallow, and deeper soil samples throughout the Landfill AOPC. Concentrations of dibenzofuran exceeded its soil SLV at approximately half the surface/shallow soil locations (everywhere it was detected) (Figure 9-1g). Concentrations of a few other SVOCs (B2EHP, carbazole, and di-n-butyl phthalate) exceeded their soil SLVs at only one or two surface/shallow soil locations (different locations for each SVOC) (see Table 9-1). In deeper soil, none of the SVOCs had concentrations that exceeded the less conservative human health soil SLVs applicable to the deeper interval (Figure 9-1h and Table 9-1).

VOCs

VOCs were detected in the majority of the surface, shallow, and deeper soil samples throughout the Landfill AOPC. Concentrations of only two VOCs (ethylbenzene and PCE) exceeded their soil SLVs (see Table 9-1), both of which were in the same sample (BIL04TPG) within the gully test pit. Ethylbenzene exceeded the more conservative ecologically based surface/shallow SLV. PCE, which was only evaluated for the deeper interval in the gully test pit samples since more recent surface/shallow samples were analyzed for PCE, exceeded the human health-based SLV for the deeper interval.

9.2.1.1 Mass Wasting Soil

Soils potentially susceptible to mass wasting along the perimeter of the Landfill AOPC are represented by fourteen surface soil locations (BIL01USE through BIL09USE, BIL13SSI, and L-01 through L-04), which were evaluated for potential impacts to the river by screening the surface soil concentrations against sediment SLVs (see Table 9-6 and Figures 9-2a and 9-2b). L-01 through L-04 were only analyzed for selected PAHs.

Metals

Metals were detected at all of the perimeter soil sample locations. Many metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, thallium, and/or zinc) were present at concentrations that exceeded sediment SLVs.

Herbicides/Pesticides

Herbicides were not detected at the single perimeter soil sample location (BIL13SSI) where herbicides were analyzed. Concentrations of the pesticides 4,4'-DDT and dieldrin exceeded their sediment SLVs at every location where they were detected (seven of 10 locations and one of 10 locations, respectively).

PCBs

PCBs were detected at nine of the 10 sample locations where PCBs were analyzed. All of the detected concentrations of total PCBs (as Aroclors) exceeded the sediment SLV.

PAHs

HPAHs and LPAHs were detected at 13 of the 14 sample locations where PAHs were analyzed. All of the detected concentrations of total HPAHs and total LPAHs exceeded their sediment SLVs

TPH

DRO, GRO, and RRO were not detected at the single location (BIL13SSI) where TPH was analyzed.

SVOCs

Other SVOCs (in addition to PAHs) were detected at the 10 sample locations where SVOCs (other than PAHs) were analyzed. Of the six SVOCs detected in the perimeter surface soil locations, two (benzoic acid and benzyl alcohol) did not have sediment SLVs, two (B2EHP and dibenzofuran) had concentrations that did not exceed their sediment SLVs, and two (and di-n-butyl phthalate and carbazole) had concentrations that only exceed their sediment SLVs at one or two locations (different for each).

VOCs

VOCs were detected at the five sample locations where VOCs were analyzed. Only three VOCs (dichloromethane, PCE, and toluene) were analyzed at four of the five locations. None of the detected concentrations exceeded the sediment SLVs.

9.2.2 Groundwater, Seep Water, and Surface Water

Nine monitoring wells (MW-1 through MW-9) were installed at the Landfill AOPC between 1998 and 2002 to evaluate potential groundwater contamination. Landfill AOPC groundwater analytical results are presented on Tables 5-1d through 5-1f, 5-2e through 5-2g, and 6-2b. Seep water analytical results are presented on Tables 5-1d through 5-1f, and 6-2b.

Metals

A variety of metals have been detected in both total and dissolved groundwater at all monitoring wells. Several metals were detected in groundwater at the Landfill AOPC at concentrations exceeding the MW-10 Reference Area concentrations (Table 8-2). Metals detected in seep water at concentrations that exceeded both Reference Area concentrations and SLVs included total arsenic, iron, lead, and manganese; and dissolved barium, iron and manganese (Table 9-7).

Several total metals concentrations (arsenic, iron, manganese, lead, and thallium) exceeded the water SLVs at all monitoring well, seep water, and surface water sampling locations (Figure 9-3a). Several dissolved metals concentrations (arsenic, barium, calcium, iron, lead, manganese, sodium, and zinc) also exceeded their water SLVs at multiple monitoring well, seep water, and surface water sampling locations (see Table 9-1), but only total concentrations were plotted on the figures. Mercury vapor lamps were identified on the surface and in the subsurface at the Landfill AOPC. However, mercury was detected in groundwater only at MW-1 and MW-3, and at concentrations below the SLVs. Mercury was not detected in seep water.

Butyltins

Butyltins were detected in groundwater at all monitoring wells except MW-9. Dibutyltin concentrations exceeded its water SLV in the majority of monitoring wells (Figure 9-3d). Monobutyltin concentrations only exceeded the water SLV in a single monitoring well (MW-2) at the southern, upgradient portion of the Landfill AOPC. In most cases, wells in which earlier samples found butyltins have subsequently been found not to contain these analytes. Butyltins were not detected in seep water or surface water.

Herbicides & Pesticides

Herbicides were detected only at MW-5 (dichloroprop) and MW-8 (4-nitrophenol and pentachlorophenol). Pesticides were detected only at MW-3 (4,4'-DDE and dieldrin). Herbicides and pesticides were not detected in seep water. Herbicides and pesticides did not exceed their water SLVs at any of the monitoring wells (see Table 9-1 and Appendix I, Table I-1).

PCBs

PCBs were not detected in groundwater or seep water at the Landfill AOPC.

PAHs

Several PAHs were detected in groundwater at MW-1, MW-4, MW-5, MW-7, MW-8, and MW-9. PAHs were not detected in seep water in 2000. Phenanthrene is the only PAH that was analyzed for in seep water or surface water in 2008, and 2009 it was not detected. Naphthalene, which was only analyzed in the 1999-2002 sampling events, had a concentration that slightly exceeded the water SLV one time at only one monitoring well (MW-1) (Figure 9-3c). Phenanthrene concentrations exceeded the water SLV at MW-4, MW-5, and MW-8 in the center of the Landfill AOPC.

TPH

DRO and RRO were detected in groundwater from all monitoring wells. GRO was detected in all monitoring wells except MW-2, MW-4, and MW-9. DRO and RRO were also detected in seep water. Only DRO was detected in surface water. DRO, GRO, and/or RRO concentrations exceeded their water SLVs at all monitoring wells (Figure 9-3b). However, concentrations of all three fractions are lower than water SLVs at the seep water and surface water locations, except DRO, which exceeded the water SLV in one of two events at S4.

SVOCs

Several SVOCs (in addition to PAHs) were detected in groundwater, at all monitoring wells except MW-7. B2EHP and DNOP concentrations exceeded water SLVs at several monitoring wells (Figure 9-3c). A single SVOC, benzoic acid, was detected in seep water in 2000 at a concentration below its SLV. Only three SVOCs (1,4-dichlorobenzene, 4-nitrophenol, and phenol) were analyzed for in seep water or surface water in 2008 and 2009; they were not detected.

VOCs

VOCs were detected in all monitoring wells except MW-1 and MW-2. Chloroform and PCE were detected in seep water but not surface water. Concentrations of chloroform, PCE, and/or vinyl chloride exceeded their water SLVs at the majority of monitoring wells (Figure 9-3d). Chloroform and PCE concentrations exceeded their water SLVs in seep water.

9.2.3 Summary

In summary, use of the Landfill AOPC to manage, store, and dispose of waste materials has resulted in contamination of soil, groundwater, and seep water with chemicals associated with the wastes. The extent of the wastes is well defined based on topography, review of historical aerial photographs, a geophysical survey, excavation of test pits, observation of wastes on the ground surface, and the analysis of soil, groundwater, seep ,and surface water samples. The type

and magnitude of contamination is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the Landfill AOPC.

Soil

Metals, PAHs, and SVOCs were detected throughout the Landfill AOPC at concentrations exceeding the SLVs. Butyltins, herbicides, pesticides, PCBs, TPH, and VOCs had generally limited detections and/or few if any exceedances of SLVs (Figures 9-4a and 9-4b). The majority of the ground surface at the Landfill AOPC is relatively flat, well vegetated, and shows minimal evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable and there is minimal potential for off-site migration of contaminated soil.

Mass Wasting Soil

The north and east sides of the Landfill AOPC include steep slopes leading down to the Columbia River. Although the potential for mass wasting appears low, a subset of the surface soil sample data (from the steep slopes) was compared to sediment SLVs to assess soil that has the potential to migrate to the river via mass wasting. Metals, pesticides, PCBs, and PAHs were detected throughout the Landfill AOPC perimeter soil samples at concentrations exceeding the SLVs. Herbicides, TPH, SVOCs, and VOCs had generally limited detections and/or few if any exceedances of SLVs.

Groundwater, Seep Water, and Surface Water

Groundwater, seep water, and surface water analytical data were compared to applicable SLVs to assess the groundwater to surface water pathway at the Landfill AOPC. Elements of this pathway include leaching of soil contaminants to groundwater and discharge of groundwater to the river either at seeps or as base flow. The direction of groundwater flow beneath the Landfill AOPC is to the north (Appendix D, Figures D-1 through D-4). Horizontal hydraulic gradients between MW-2 and MW-5 in the Landfill AOPC range from 0.10 to 0.13 foot per foot (Appendix D, Table D-2). Metals, TPHs, and VOCs were detected in groundwater throughout the Landfill AOPC, as well as in seep water, at concentrations exceeding the SLVs. Metals and DRO were also detected in surface water at concentrations exceeding the SLVs. Butyltins, herbicides, pesticides, PCBs, PAHs, and SVOCs had generally limited detections in groundwater and/or few if any exceedances of SLVs. Butyltins, herbicides, pesticides, PCBs, and PAHs were not detected in seep water.

9.3 Sandblast Area AOPC Nature and Extent of Contamination

As previously described, contamination at the Sandblast Area AOPC resulted from a variety of historical and ongoing uses that include equipment storage and management, storage, and disposal of various hazardous materials and wastes. The Sandblast Area AOPC has been divided into subareas corresponding to the different uses and associated known or potential sources of contamination: the septic tank drain field area, the spent sandblast media disposal area, two HMSAs, a transformer disassembly area, an equipment laydown area, and a former burn pit (Figure 3-4). The two HMSAs include the former HMSA, also referred to as the drum storage area, and the current HMSA located immediately southeast of the former sandblast building. The former HMSA was investigated because various hazardous and non-hazardous materials were stored there from the early 1980s to the early 1990s and the former HMSA pad did not have secondary contaminant or protective berms. The current HMSA has secondary containment and

no document releases have occurred in this area since its construction. Prior to construction of the current HMSA, a storage tank was reportedly present at this location that is inferred to have been the source of a historical release of VOCs to adjacent soils.

Several site investigations have occurred at the Sandblast Area AOPC since 2001 that focused on individual subareas within the Sandblast Area AOPC and/or the media associated with the individual subareas. Based on the results of these investigations, the three subareas that appear to be the primary sources of contamination are the sandblast grit disposal area, the equipment laydown area, and an inferred VOC release at the current HMSA (Figure 3-4).

There are only three sample locations (DP11, DP12, and HA12) that were sampled in deeper soil (3-10 feet bgs) at the Sandblast Area AOPC. Due to the limited number of samples within the 3-10 feet bgs interval, six very deep samples (DP5 through DP10 sampled at > 10 feet bgs) were also included in the evaluation of the deeper soil for nature and extent at the Sandblast Area AOPC. Note that DP10 (sampled at 9-12 feet bgs) was not included in the deeper soil interval (0-10 feet bgs) because most of the sampling interval was greater than 10 ft.

The topography of the Sandblast Area AOPC generally consists of a north facing slope with numerous topographic complexities. Upslope of the former sandblast building is a relatively undisturbed and densely vegetated hill slope. Below the upper hill slope is a relatively flat and paved area around the former sandblast building. Downslope (to the north-northeast) of the former sandblast building and the adjacent paved area is a short, steep forested hill slope leading to the flat equipment laydown area and the paved road leading east to the Landfill AOPC. Downslope (to the northwest) of the former sandblast building is a relatively flat, vegetated area, followed by a recently disturbed slope, then a paved road. Recent excavation and filling activities on the slope removed vegetation and exposed bare, erodible soils at the ground surface immediately upslope of CB-2.

Within the Sandblast Area AOPC, a portion of the stormwater runoff from impervious surfaces (asphalt) drains to four catch basins that discharge to the Columbia River through two outfalls. It appears, however, that the majority of the runoff from asphalt immediately southeast of the former sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. Eroded soil from the rills combined with sandblast grit from further upslope has been observed accumulated at the base of the slope and behind one of two concrete curbs that run along the base of the slope at the equipment laydown area (URS 2009f).

Evidence of runoff was observed along the Landfill access road and the adjacent equipment laydown area. These areas are flat and evidence of erosion is generally lacking. Runoff from the road appears to flow north onto a vegetated area between the Landfill road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates before reaching the river (URS 2009f). Within the remainder of the Sandblast Area AOPC, in particular vegetated areas, no evidence of surface runoff, soil erosion, or sediment deposition was observed. In summary, the only complete pathway for direct discharge of surface water from the Sandblast Area AOPC to the river is via the four catch basins.

9.3.1 Soil

Extensive investigations of the surface/shallow soil have occurred throughout the Sandblast Area AOPC and its subareas, as well as along stormwater flow paths and adjacent to catch basins. One hundred and eighteen surface and shallow samples have been collected. Deeper and very deep soil samples are limited to nine locations within two subareas: the current HMSA and the septic tank drain field area (see Figure 9-5i). Soil analytical results are present on Tables 5-4a through 5-4e, 5-5a through 5-5c, and 6-3a through 6-3g. Appendix I, Table I-2 presents the summary statistics and detection frequency for the Sandblast Area AOPC data.

Metals

Metals were analyzed in surface and shallow soil samples throughout the Sandblast Area AOPC, including all subareas, as well as along the stormwater flowpath CB-1 and adjacent to CB-1. Metals were detected in surface and shallow soil throughout the Sandblast Area AOPC. Relatively elevated concentrations of metals were associated primarily with the spent sandblast media disposal subarea, the equipment laydown subarea, and to a lesser extent the former HMSA subarea, indicating these three subareas are the primary sources of metals in soil. Elevated concentrations of metals were also detected in soil samples collected at or near CB-1, indicating that transport of metals from potential source areas to the catch basin via the stormwater pathway has occurred. Concentrations of several metals (antimony, arsenic, cadmium, chromium, lead, nickel, selenium, and/or zinc) exceeded soil SLVs at most surface/shallow soil locations (Figures 9-5a through 9-5d).

Metals were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea and four borings at the current HMSA subarea. At the septic tank drain field subarea, concentrations in deeper soil and very deep soil (>10 feet bgs) for the eight metals listed above were generally lower than the surface and shallow concentration. The only exceptions were antimony, which had similar concentration, and arsenic, which had higher concentrations than in surface/shallow soils. At the current HMSA subarea all eight metals had lower concentrations than the corresponding surface and shallow soils (Figure 9-5e). Only arsenic and chromium concentrations exceeded the less conservative human health soil SLVs that are applicable to the deeper soil intervals.

Potential correlations among concentrations of the eight metals detected above their soil SLVs were examined. Concentrations of each metal were compared to each of the other metals (e.g., lead and chromium, lead and cadmium, chromium and cadmium, etc) by plotting the paired data for each location on scatter plots. Best-fit linear regression lines were calculated, along with the resulting r-squared values. Initially, the data set was divided into the following three data sets:

- Surface soil (0-1 foot bgs) in the southern portion of the Sandblast Area AOPC within/surrounding the former HMSA.
- Surface soil (0-1 foot bgs) in the remaining portion (northern portion) of the Sandblast Area AOPC.
- Subsurface soil (1-3 feet bgs) in the northern portion of the Sandblast Area AOPC.

Little evidence of correlation was found in any of these data sets. The surface soil (0-1 foot bgs) in the northern portion of the Sandblast Area AOPC was then divided into two subgroups based on samples that were noted for having higher soil or higher sandblast grit composition. The only

correlation that was present was for chromium and nickel (r^2=0.93) in surface soil samples. This is consistent with the historical use of a chromium-nickel based coating system for some of the equipment which likely was sandblasted at the former sandblast building. No other correlations between metals concentrations were found.

Butyltins

Butyltins were analyzed in surface and shallow soil samples from the septic tank drain field, spent sandblast media disposal, current HMSA, transformer disassembly, and the equipment laydown subareas, as well as in one sample from the former HMSA, and several samples along the stormwater flow path to CB-1, and at CB-1. Butyltins were detected at the septic tank drain field, spent sandblast media disposal, current and former HMSA, and the equipment laydown subareas. Butyltins were also detected in samples along the stormwater flowpath to CB-1, but were not detected in soil samples at CB-1.

Butyltins were only analyzed in deeper soil at five borings located at the septic tank drain field subarea. Butyltins were detected at all five borings at depths ranging from 13 to 23 feet bgs (the samples depths corresponded to the depth where groundwater was first encountered in each boring).

Some butyltins were detected in less than 5% of samples (e.g., tetrabutyltin) and all butyltins had concentrations less than their soil SLVs in surface, shallow, deeper and very deep soil (see Table 9-2 and Appendix I, Table I-2).

Herbicides & Pesticides

Herbicides analyses were conducted on 12 surface soil samples at the former HMSA. No herbicides were detected (see Appendix I, Table I-2).

Pesticides were analyzed for and detected in surface and shallow soil samples at the septic tank drain field, spent sandblast media disposal, equipment laydown, and former HMSA subareas. Concentrations of several pesticides (4,4'-DDT, endrin, endrin aldehyde, and endrin ketone) exceeded soil SLVs within the surface soil at six locations at the east end of the equipment laydown subarea, and one location at the former HMSA subarea (Figure 9-5f). In one equipment laydown subarea sample, 4,4'-DDT also slightly exceeded the soil SLV in shallow soil. Pesticides analyses in deeper and very deep soil were limited to five borings located at the septic tank drain field subarea. Pesticides were not detected at these boring locations (see Table 9-2 and Appendix I, Table I-2).

PCBs

PBCs were analyzed in surface and shallow soil samples throughout the Sandblast Area AOPC, including all subareas, as well as along the stormwater flowpath to CB-1 and at CB-1. PCBs were detected in most or all of the samples from each subarea. PCBs were also detected in all samples along the stormwater flow path to CB-1 and in all samples at CB-1, indicating that transport of PCBs from potential source areas to the catch basin via the stormwater pathway has occurred. Concentrations of total PCBs (as Aroclors) exceeded soil SLVs at only six surface soil locations, limited to the northeastern portion of the east end of the equipment laydown subarea (Figure 9-5g). PCB concentrations were lower than the soil SLV in all shallow soil samples.

PCBs were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea; PCBs were not detected (see Table 9-2 and Appendix I, Table I-2).

PAHs

PAHs were analyzed in surface and shallow soil samples at the septic tank drain field, spent sandblast media disposal, current HMSA, former HMSA, and equipment laydown subareas. PAHs were detected at all sample locations. Total HPAH concentrations exceeded the soil SLV at over half of the surface/shallow soil locations, including every subarea (Figure 9-5h). Total LPAH concentrations are lower than soil SLVs at all surface/shallow locations (Figure 9-5h).

PAHs were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea and four borings at the current HMSA subarea. PAHs were detected in three of the five septic tank drain field subarea borings and one of the four current HMSA borings. There is no soil SLV applicable to total HPAHs in the deeper or very deep soils. Concentrations of several of the individual HPAHs exceeded the human health soil SLVs applicable to deeper soil but none of the individual HPAHs exceeded the human health soil SLVs in very deep soil (see Table 9-2). There is no soil SLV applicable to total LPAHs in the deeper or very deep soils. However, none of the individual LPAHs exceeded the applicable soil SLVs in surface, shallow, deeper, or very deep soil (see Table 9-2).

TPH

TPHs were analyzed in surface and shallow soil samples throughout the Sandblast Area AOPC, including all subareas, as well as along the stormwater flowpath to CB-1 and adjacent to CB-1. TPHs were detected in most or all of the samples from each subarea. TPHs were also detected in all samples along the stormwater flow path to CB-1 and in all samples at CB-1, indicating that transport of TPHs from potential source areas to the catch basin via the stormwater pathway has occurred. DRO and RRO were the most frequent detections; detections of GRO were infrequent. However, TPH concentrations were less than their soil SLVs in all surface and shallow soil samples (see Table 9-2).

TPHs were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea and four borings at the current HMSA. TPHs were not detected in deeper or very deep soils (see Appendix I, Table I-2).

SVOCs

In addition to PAHs, other SVOCs were analyzed in surface and shallow soil samples at the septic tank drain field, spent sandblast media disposal, current HMSA, and former HMSA, and equipment laydown subareas. SVOCs were detected in most or all of the samples from each of these subareas. Concentrations of B2EHP and dibenzofuran exceeded their soil SLVs at approximately 1/3 and 1/2 of the surface and shallow soil locations, respectively, with exceedances for one or both chemicals in all subareas sampled (Figure 9-5h).

SVOCs were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea and four borings at the current HMSA subarea. SVOCs were detected at every boring (see Appendix I, Table I-2) but all detected concentrations were less than the less conservative human health soil SLVs applicable to the deeper intervals (Figure 9-5i).

VOCs

VOCs were analyzed in surface and shallow soil samples at the septic tank drain field, spent sandblast media disposal, current HMSA, former HMSA, and equipment laydown subareas. A single VOC, PCE, was detected at only one of the 12 sample location at the former HMSA

subarea. VOCs were detected at relatively low concentrations in all samples from the remaining subareas, with the exception of the current HMSA, where very high concentrations of PCE (420,000 micrograms/kilograms [µg/kg] at sample SBB18) and trichloroethene (TCE) (6,080 µg/kg at sample HA4) were found (Figure 9-5j). PCE and TCE exceeded their soil SLVs at both of these two sample locations. No other VOCs exceeded SLVs at SBB18 and HA4, and there were no other SLV exceedances elsewhere at the Sandblast Area AOPC.

VOCs were only analyzed in deeper and very deep soil at five borings located at the septic tank drain field subarea and four borings at the current HMSA subarea. VOCs were detected in every deeper and very deep soil sample (see Appendix I, Table I-2) but all detected concentrations were less than the SLVs (Figure 9-5k).

9.3.1.1 Erodible Soil

The erodible soils in the northwest portion of the Sandblast Area AOPC, identified in 2008 as a result of recent soil disturbance, are represented by two composite surface samples (SB-EUA and SB-EUB) that were analyzed for metals, PCBs, TPH, butyltins, pesticides, SVOCs, and PAHs, eight surface subsamples (SB-EUA-02, SB-EUA-04, SB-EUA-06, SB-EUA-08, SB-EUB-02, SB-EUB-03, SB-EUB-12, and SB-EUB-15) that were analyzed for VOCs, and an additional surface sample (SB-04) only analyzed for lead. Although this area has subsequently become naturally revegetated, these erodible soils were evaluated for potential impacts to the river by screening the surface soil concentrations against sediment SLVs (see Table 9-6 and Figure 9-6).

Metals

Twenty-three metals were detected in composite samples SB-EUA and SB-EUB. Lead was also detected in sample SB-04. Lead exceeded sediment SLVs at all three locations. Cadmium, chromium, copper, and nickel had concentrations that exceeded sediment SLVs in both of the two composite samples. Zinc exceeded the sediment SLV in only one of the two.

Organics

PCBs, TPH, butyltins, pesticides, SVOCs, and PAHs were detected in both composite samples. VOCs were detected in all eight subsamples. There are no sediment SLVs available for TPH, several pesticides, the majority of VOCs, and two of the three detected butyltins. Of the chemicals with available SLVs, concentrations of tributyltin, two pesticides (4,4'-DDT and 4,4'-DDE), total PCBs (as Aroclors), total HPAHs and total LPAHs, and one of two detected SVOCs (B2EHP) exceeded their sediment SLVs in both composite samples. The only VOC with a sediment SLV (naphthalene) was detected at concentrations less than the sediment SLV in all eight subsamples.

9.3.2 Groundwater

Groundwater investigations at the Sandblast Area AOPC focused on the current HMSA, spent sandblast media disposal, septic tank drain field, transformer disassembly, and equipment laydown subareas. Reconnaissance groundwater samples were collected in 2004 from 10 direct-push borings (DP1 through DP5, DP7, and DP9 through DP12; Tables 5-5d through 5-5g). Since these samples were collected from temporary borings, as opposed to properly developed monitoring wells, there is a potential for entrainment of soil particles in these groundwater samples, which can bias the results towards increased concentrations in groundwater. In 2008 and 2009 four quarterly groundwater sampling events were completed at five newly-installed

monitoring wells (MW-11 through MW-15; Tables 6-3h and 6-3i). The groundwater data from monitoring wells are more representative of actual chemicals that are present and potentially mobile in groundwater, and are therefore the focus of the discussion below.

Groundwater elevations measured at MW-11 through MW-15 indicate that the direction of groundwater flow is north-northwest (Appendix D, Figure D-5 through D-8) at a gradient of 0.08 to 0.11 ft/feet (Appendix D, Table D-2). Based on this groundwater flow direction, the distribution of soil borings and monitoring wells relative to the gradient and direction of groundwater flow at the Sandblast Area AOPC are as follows:

- DP10 through DP12 and MW-11 are located at the upgradient edge.
- DP1 through DP4, MW-14, and MW-15 are located at the downgradient edge, just prior to groundwater discharge to the river.
- DP5, DP7, DP9, MW-12, and MW13 are at intermediate locations between the upgradient and downgradient edges.

Metals

Metals were detected in samples from all 10 borings and five monitoring wells. Total metals were detected at concentrations exceeding their water SLVs at all sampling locations except DP9 (Figure 9-7a). Arsenic, iron, and vanadium had concentrations that exceeded their water SLVs at the majority of the soil borings and at one or more monitoring wells. However, only arsenic concentrations consistently exceeded the water SLV in the monitoring wells. Cobalt and manganese had concentrations that exceeded their water SLVs at one or more of the borings, but were not analyzed in the monitoring well samples. Several dissolved metals (aluminum, arsenic, barium, iron, manganese, and vanadium) also had concentrations that exceeded their water SLVs at direct push sampling locations and monitoring wells (see Table 9-2), but only total concentrations were plotted on the figures. Note that essential nutrients (e.g., iron) were not evaluated in soil, but they were evaluated for groundwater. Based on these data, including exceedances of SLVs in downgradient borings and monitoring wells, it appears that metals in soil are leaching to groundwater and groundwater with concentrations of some metals exceeding applicable SLVs may be discharging to the river.

Butyltins

Groundwater samples were analyzed for butyltins at DP1 through DP4 and all five monitoring wells. Butyltins were detected at DP2 through DP4, MW-11, and MW-13. The detections at MW-11 and MW-13 indicate butyltins may be leaching to groundwater. The detections at DP2 through DP4 suggest butyltins in groundwater may be migrating downgradient. However, butyltins were not detected at the downgradient monitoring wells MW-14 and MW-15, or at downgradient boring DP1, suggesting that the detections at DP2 through DP4 may not be representative of actual butyltin concentrations in groundwater. None of the detected concentrations of butyltins exceeded the SLVs (see Table 9-2).

Herbicides & Pesticides

Since herbicides were not detected in soil at the former HMSA, and there are no records of herbicide use or management in other areas of the Sandblast Area AOPC, herbicides were not analyzed in groundwater.

Pesticides were analyzed in groundwater samples from DP5, DP7, and DP9, and detected at all three locations. The detected concentrations were lower than the SLVs and therefore pesticides were not analyzed in samples from the monitoring wells (see Table 9-2 and Appendix I, Table I-2).

PCBs

PCBs were analyzed in groundwater samples from DP1 through DP5, DP7, and DP9. PCBs were not detected in any of these samples, and therefore were not analyzed in samples from the monitoring wells (see Appendix I, Table I-2).

PAHs

PAHs were analyzed in groundwater samples from all monitoring wells and borings except boring DP12. The boring analyses included both unfiltered (total PAH) and filtered (dissolved PAH) samples to reduce the uncertainty associated with entrainment of soil particles in groundwater samples collected from soil borings. Groundwater analyses from the monitoring wells were limited to three PAHs (benzo(b)fluoranthene, benzo(k)fluoranthene, and phenanthrene). All boring groundwater samples had detections of total or dissolved PAHs, except DP9 where total PAHs were not detected. Total and/or dissolved concentrations of the HPAHs benzo(a)pyrene, total benzofluoranthenes, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded their SLVs at DP7. Two LPAHs (dissolved naphthalene and total phenanthrene) had concentrations that exceeded their water SLVs at DP2, DP4, DP7, and DP10. PAHs were not detected in samples from the monitoring wells with the exception of benzo(b)fluoranthene, which was detected during only one of the four sampling events at MW-12 and at a concentration above its SLV. Since it was detected at a frequency of only 5% it was not retained as a preliminary COPC.

The detection of dissolved concentrations of PAHs at every direct push boring, including all four downgradient borings, suggests PAHs may be leaching to groundwater and migrating toward the river. PAHs were not detected in the two downgradient monitoring wells MW-14 and MW-15, however only a subset of the PAHs detected in the samples from the direct-push borings were analyzed for in the monitoring wells. This lack of PAH data from the monitoring wells represents a potential data gap.

TPH

TPHs were analyzed in groundwater samples from all monitoring wells and borings except the downgradient borings DP1 through DP4. TPHs were detected at the upgradient locations DP10, DP11 and MW-11, and at the intermediate locations DP7, MW-12, and MW-13. TPHs were not detected at the upgradient location DP12, intermediate locations DP5 and DP9, and downgradient locations MW-14 and MW-15. None of the detected concentrations of TPHs exceeded their water SLVs (see Table 9-2). Although TPHs appear to be leaching to groundwater, they do not appear to be migrating toward the river.

SVOCs

SVOCs, excluding PAHs, were analyzed in groundwater from every boring except DP12, and detected at each of the sampled borings. Dissolved SVOCs were analyzed at every boring except DP11 and DP12 and detected at each of the sampled borings. All detected concentrations were less than their water SLVs (see Table 9-2) and therefore SVOCs were not analyzed for in

monitoring wells. Although SVOCs appear to be leaching to groundwater, they do not appear to be migrating toward the river at concentrations of concern.

VOCs

VOCs were analyzed for, and detected, in groundwater from all 10 borings and all five monitoring wells. Concentrations of one or more VOCs exceeded their water SLVs at all borings, and at MW-12 through MW-15. Concentrations of PCE and/or TCE exceeded their water SLVs at all borings and MW-12 through MW-15. The concentration of 1,1-DCA exceeded the water SLV only at DP5 and MW-12. The concentrations of cis-1,2- dichloroethene (DCE) exceeded the water SLV only at MW-12. Vinyl chloride exceeded its water SLVs at DP11, DP5, and MW-12.

As shown on Figure 9-7b, the groundwater data from borings delineated a PCE plume in 2004 with concentrations greater than 10 times the SLV, starting at DP11 (next to the HMSA) and continuing downgradient toward the river. Similarly, the 2008/2009 monitoring well data delineated a PCE plume with concentrations greater than 10 times the SLV starting at MW-12 (north of the former sandblast building) and continuing downgradient toward the river.

As described above, prior to construction of the current HMSA, a storage tank was reportedly present at this location. Significantly elevated concentrations of VOCs are present in soil at the current HMSA subarea. The boring and monitoring well groundwater data confirm that VOCs, in particular PCE and TCE, have leached from and are likely continuing to leach from soil to groundwater from this source area and are migrating toward the river at concentrations of potential concern. However, as shown on Figure 9-7b, the extent of the plume with concentrations exceeding 10 times the SLV did not include the source area in 2008 (as it did in 2004), suggesting that the mass of VOCs available to leach to groundwater is decreasing over time. The breakdown products of PCE (1,1-dichloroethane [DCA] , cis-1,2-DCE, and vinyl chloride) were also present in groundwater but at generally lower concentrations and with fewer SLV exceedances.

9.3.3 Soil Gas

Soil gas samples were analyzed at five borings (SB-10 through SB-14). Three of the soil borings (SB-10 through SB-12) were installed at and downgradient of the VOC source area associated with the former storage tank at the current HMSA subarea. The other two soil borings (SB-13 and SB-14) were installed along the southwest edge of the Sandblast Area AOPC, adjacent to the Service Center and Equipment Buildings (the closest occupied structures).

VOCs were detected in soil gas from all five borings. However, exceedances of the soil gas SLVs were limited to TCE at soil boring SB-10 (located adjacent to the current HMSA), and PCE and TCE at SB-12 (located adjacent to the former sandblast building); both borings are within the footprint of the PCE groundwater plume (Figure 9-8). Other breakdown products of PCE (1,1-DCE, cis-1,2-DCE, trans-1,2,-DCE, and vinyl chloride) were not detected above their soil gas SLVs at these two locations). The sandblast building (recently demolished), current HMSA, and the adjacent outdoor areas are not occupied by site workers. There were no exceedances of the soil gas SLVs at soil borings SB-13 and SB-14, which are located adjacent to buildings that are occupied by site workers.

9.3.4 Summary

In summary, historical and ongoing uses of the Sandblast Area AOPC include equipment storage and management, storage, and disposal of various hazardous substances and wastes. These uses have resulted in contamination of soil, groundwater, and soil gas with chemicals associated with the equipment and wastes. The extent of the contaminated area is defined based on topography, location of former and existing site features and structures, knowledge of former and current site uses, visual observation of wastes (i.e. sandblast grit) and equipment on the ground surface, and the analysis of soil, groundwater, and soil gas samples. The type and magnitude of contamination is variable, consistent with the variable hazardous substance and waste management, storage, and disposal practices that occurred at the various subareas within the Sandblast Area AOPC. The sandblast grit disposal area, the equipment laydown area, and an inferred VOC release at the current HMSA appear to be the primary sources of contamination.

Soil

Metals, pesticides, PCBs, PAHs, SVOCs, and VOCs were detected at the Sandblast Area AOPC at concentrations exceeding the SLVs. Metals concentrations exceed soil SLVs throughout the Sandblast Area AOPC, including all subareas. Pesticide and PCB concentrations exceeded soil SLVs primarily at the east end of the equipment laydown subarea (Figure 9-9a). PAHs and other SVOCs exceeded SLVs throughout the Sandblast Area AOPC (Figures 9-9b and 9-9c). VOC concentrations exceeded SLVs only in soil immediately adjacent to the current HMSA.

TPHs and butyltins were detected in soil samples throughout the Sandblast Area AOPC, but at concentrations below the SLVs. Herbicides were not detected in soil.

Metals, butyltins, PCBs, and TPHs were detected in soil along the stormwater flow path to CB-1, and/or in soil immediately adjacent to CB-1, indicating that contaminant transport from potential source areas to the catch basin via the stormwater pathway has occurred. Since pesticides, PAHs, SVOCs, and VOCs were not analyzed in soil along the stormwater flow path or at CB-1, it is not known whether these chemicals are being transported via the stormwater pathway. However, since all other analyte groups that were detected elsewhere at the AOPC were also detected along the stormwater flow path or at CB-1, it is possible that pesticides, PAHs, SVOCs, and VOCs are also being transported along this pathway.

Erodible Soil

Potentially erodible soils were identified in March 2009, resulting from late 2008 excavation and filling activities were identified on a slope northwest of the former sandblast building. Metals, PCBs, TPH, butyltins, pesticides, SVOCs, PAHs, and VOCs were detected in samples of the erodible soil. Seven metals, tributyltin, two pesticides, total PCBs, total HPAHs, total LPAHs, and a single SVOC exceeded their sediment SLVs. As expected, the disturbed area has become naturally revegetated (see the photographs in Appendix C), and now resembles other vegetated slopes in the Sandblast Area AOPC that show no evidence of surface runoff, soil erosion, or sediment deposition.

Groundwater

Groundwater data were compared to applicable SLVs to assess the groundwater to surface water pathway at the Sandblast Area AOPC. Elements of this pathway include leaching of soil contaminants to groundwater and discharge of groundwater to the river as base flow. Seeps have

not been observed along the riverbank at the northern margin of the Sandblast Area AOPC. Metals, butyltins, pesticides, PAHs, TPHs, SVOCs, and VOCs were detected in groundwater, indicating that these contaminants are leaching from source area soils to groundwater. PCBs were not detected. Concentrations of metals, PAHs, and VOCs in groundwater exceeded their surface water SLVs, including at locations immediately adjacent to the river, indicating that these contaminants may be migrating to the river at concentrations of potential concern. Butyltin, pesticide, TPH, and SVOC concentrations did not exceed SLVs.

Soil Gas

VOCs were detected in soil gas at locations corresponding to the footprint of the VOC plume originating at the current HMSA (Figure 9-10). PCE and TCE exceeded their soil gas SLVs only in areas where there are no structures that could be occupied by site workers.

9.4 Pistol Range AOPC Nature and Extent of Contamination

As described previously, contamination at the Pistol Range AOPC resulted from historical use of the area as a firing range. Located on the south side of Bradford Island, existing structures at the Pistol Range AOPC include a collapsed wooden firing shed, a secondary firing location, and a timber backstop. Based on the location of these structures as well as observation of the area on historical aerial photographs, the Pistol Range AOPC is approximately 200 feet long, 20 to 30 feet wide, and covers an area of approximately 4,550 square feet.

The overall slope of the Pistol Range AOPC is to the southeast toward the Columbia River. The topography of the area consists of a series of cuts and fills, resulting in a sequence of slopes and flat areas. Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation and does not show evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. When the Pistol Range AOPC was in use as a firing range the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River.

9.4.1 Soil

Surface (0-0.5 feet bgs) and near surface (1.0-1.5 feet bgs) soil samples were collected from within and adjacent to the Pistol Range AOPC and analyzed for lead. Subsets of the samples were analyzed for antimony, arsenic, copper, mercury, nickel, and zinc. Antimony, arsenic, and mercury were not detected. Copper and nickel were detected but at concentrations below their soil SLVs. With a few exceptions, lead and zinc concentrations in soil exceed their respective SLVs throughout the Pistol Range AOPC. The highest concentrations of lead were detected at and behind the backstop. The analytical data are summarized in Tables 5-6 and 9-3, as well as Appendix I, Table I-3. Sample locations and data for lead and zinc are shown on Figure 9-11.

9.4.2 Groundwater

Grab groundwater samples were collected from two temporary borings at the Pistol Range AOPC and analyzed for total and dissolved concentrations of copper, lead, nickel, and zinc. The analytical data are summarized in Table 6-4b; groundwater sample locations and data for lead and zinc are shown on Figure 9-11. Total concentrations of all four metals were detected in both samples, but no concentrations exceeded the water SLVs.

9.4.3 Lagoon Sediment

Five sediment samples were collected from a shallow lagoon in the Columbia River adjacent to the Pistol Range AOPC and analyzed for copper, lead, nickel, and zinc. The analytical data are summarized on Table 6-4a; sediment sample locations and data for lead and zinc are shown on Figure 9-11. All four metals were detected in all five samples. Copper, lead, and nickel did not exceed their sediment SLVs, but zinc exceeded its sediment SLV at all five sample locations. The zinc concentrations are all higher than the maximum concentration of zinc detected elsewhere in Forebay sediments (113 mg/kg), suggesting that the Pistol Range AOPC may be a historical source of zinc in the lagoon sediment.

9.4.4 Summary

In summary, use of the Pistol Range AOPC as a firing range has resulted in the contamination of surface soil with lead and zinc. Nearly all surface soil sample locations have lead and zinc present at concentrations that exceed soil SLVs. It is unlikely that significant concentrations of lead or zinc are leaching to groundwater since the groundwater SLVs are not exceeded. The Pistol Range AOPC may also be a historical source of zinc to the adjacent lagoon sediment. Currently, the area is currently well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition.

Further investigation of the soil northeast of the backstop may be required to determine the full extent of contaminated soil in this area.

9.5 Bulb Slope AOPC Nature and Extent of Contamination

As previously described, contamination at the Bulb Slope AOPC resulted from placement of glass and electrical light bulb debris directly onto a steep slope between the Landfill access road and the Columbia River on the north side of Bradford Island. The debris include various types of light bulbs, glass tubes, clear window pane glass, white molded glass, and miscellaneous glass beverage containers that are variably intermixed with silt, sand, gravel, cobbles, and concrete rubble. The width of the deposit across the slope ranges from 30 to 65 feet, and the length of the deposit from the top of the slope to the river is about 40 feet. The deposit ranges in thickness from about 4 inches near the top of the slope to 5 feet at the base of the slope, and is underlain by siltstone bedrock. Concrete rubble and a small amount of glass debris have been observed in the Columbia River near the riverbank at the base of the Bulb Slope AOPC. The total area of the deposit is about 1,900 square feet (Figure 9-12).

The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface runoff or overland flow to the river. At the base of the slope, however, wave erosion has resulted in mass wasting (small slope failures) of material into the river. Mass wasting appears to be the only potential mechanism for transport of debris and/or contaminated soil into the river.

Twelve surface soil samples were collected from within the area visibly impacted by glass and light bulb debris and analyzed for lead, mercury, and PCBs (as Aroclors). Lead and mercury were detected in all 12 samples. PCBs were detected in eight of the 12 samples. TPH was analyzed for and detected in eight of the 12 samples. The analytical data are summarized in

Tables 5-7, 9-4, and 9-6, as well as Appendix I, Table I-4. Sample locations and data are shown on Figure 9-12.

Since mass wasting is a potential pathway for migration of contaminants to the river, the surface soil data were compared to soil SLVs as well as sediment SLVs. Eleven of the 12 detected concentrations of lead and 10 of the 12 detected concentrations of mercury exceeded soil SLVs. Sediment SLVs are not available for TPH. Eleven of the 12 detected concentrations of lead, six of the 12 detected concentrations of mercury, and all of the eight detected concentrations of PCBs exceeded the sediment SLVs (Figure 9-13).

In summary, placement of debris at the Bulb Slope AOPC has resulted in the contamination of soil with lead, mercury, PCBs, and TPH. All surface soil sample locations have one or more contaminants present at concentrations that exceed the applicable soil and/or sediment SLV. The lateral extent of contamination is well constrained by the visible presence of debris in the soil. The underlying siltstone bedrock defines the vertical extent of contamination.

9.6 River OU Nature and Extent of Contamination

As described in Section 3.5.2, electrical equipment debris was historically disposed of directly in the River on the north side of Bradford Island. Figure 3-5 depicts the in-water historical source locations, identified as Former Debris Piles (#1 through #3). The electrical equipment debris included light ballasts, electrical insulators, lightning arresters, electrical switches, rocker switches, a breaker box, and electrical capacitors. The electrical debris contaminated the surrounding sediment with PCBs and potentially other COIs. The electrical equipment debris were removed in 2000 and 2002 (URS 2002b) and the majority of the associated PCB-contaminated sediment was removed in 2007 (URS 2008f and URS 2009d). Residual contaminated sediment, as well as historically contaminated biota (e.g., fish and shellfish) may currently be sources of contamination.

The Columbia River is a dynamic environment in which sediment is constantly being redistributed through human and natural processes. As described in Section 6.0, this RI focuses on conditions in the River OU following the sediment removal effort. Immediately prior to the 2007 removal of contaminated sediments north of Bradford Island, samples of sediment and clams were collected from areas targeted for dredging. These Pre-removal data do not identify any additional preliminary COPCs (see Appendix O), and they are not representative of current Post-removal concentrations, they are not discussed further in the summary of nature and extent of COPCs in the River OU. The pre-removal data are considered further in the uncertainty sections of the HHRA and ERA (see Appendix O).

Historical sampling (discussed in Section 5.0), supported by hydrologic modeling, demonstrated that sediment from the Forebay is not transported upstream beyond Goose Island. Therefore, the upstream boundary of the River OU is the northern end of Goose Island (Figure 1-3). The other boundaries of the River OU include the Bonneville Dam and Spillway, the two powerhouses, and the riverbanks of the Columbia River. Evidence that site-related COIs have not been transported downstream of the dam is discussed in Section 9.6.1, followed by a discussion of nature and extent of COIs within the boundary of the River OU.

9.6.1 Downstream Sediments

As described in Section 8.2.3, six sediment samples were collected from likely depositional areas downstream of the dam, and analyzed to assess the potential for sediment impacts related to releases from the site. These sediment samples were analyzed for metals, TPH-Dx, PCBs, and PAHs. Table 9-12 compares the maximum COIs concentrations detected in the downstream sediments with the 95% UPLs for Reference Area sediment and the sediment SLVs. The only two COIs for which both the 95% UPL and the sediment SLV is exceeded are cadmium and vanadium. In both cases, only a single sample out of the six is higher, and only by a small amount (Table 9-12).

These data demonstrate that the contamination related to Bradford Island is restricted to the Forebay. No detectable contamination has migrated downstream. The extent of the contamination is therefore well constrained on the downstream end by the dam and spillways, and on the upstream end by the eastern end of Goose Island (the upstream limit to which numerical modeling suggests that sediment may be transported upstream).

9.6.2 Forebay – Random and Targeted Samples

The nature of the contamination in the Forebay has been characterized by both random and targeted sampling of surface water, sediment, and various tissues. Each of these media is discussed below.

9.6.2.1 Surface Water

A total of five surface water samples were collected to document conditions in the Forebay. Grab samples were analyzed for total and dissolved metals and TPH-Dx. XAD samples were analyzed for PCB Congeners and PAHs. Data are summarized in Tables 6-12 and 9-8. Since the surface water flows steadily through the Forebay, no spatial variation in surface water concentrations is expected or observed. All five samples are interpreted as representative snapshots of Forebay surface water conditions.

The only metals that exceeded SLVs were arsenic (total and dissolved) and barium (dissolved only); the only organic compounds exceeding SLVs were total PCBs as congeners (Table 9-8). No SLVs are available for total LPAHs or HPAHs; however concentrations of the individual PAH concentrations were all below the individual SLVs.

As discussed in Section 8.2.1, the range of concentrations of arsenic detected in the Forebay surface water were less than the range of concentrations detected in the River Reference Area (see Table 8-4). Therefore, although surface water concentrations of arsenic, barium, and total PCBs may pose a potential risk to ecological or human health, the arsenic does not appear to be related to site releases. These preliminary COPCs are evaluated further in the HHRA and ERA (Chapters 11 and 12).

9.6.2.2 Sediment

Sediment data from the 19 random Forebay locations are summarized in Tables 6-8a and 9-8. Sediment data from the targeted sample locations are summarized in Table 6-13b; Appendix I, Tables I-9a and I-9b; and Appendix L, Table L-7. Concentrations of selected metals and of total PCBs are plotted in Figures 9-14a through 9-14e.

Metals were detected in all of the random and targeted sediment samples. A few individual samples (random and targeted) had concentrations of cadmium (six samples, Figure 9-14b), mercury (five samples, Figure 9-14d), nickel (one sample), thallium (one sample) and zinc (one sample) above their SLVs. However, as discussed in Section 8.2.1, population-to-population statistical comparisons show that for all metals, concentrations observed in the Forebay sediment samples were not significantly higher than the concentrations observed in the Reference Area samples (Table 8-2). Therefore, although concentrations of selected metals in Forebay sediments exceeded conservative SLVs, they do not appear to be site related.

As presented in Section 8, the comparison of the targeted Eagle Creek and Goose Island sediment samples to the Reference Area data (Appendix L, Table L-7) shows that concentrations of all metals at Eagle Creek and all metals except antimony, cadmium, thallium, and zinc at Goose Island were less than the Reference Area concentrations.

None of the random or targeted sediment samples had SVOC concentrations exceeding SLVs (Tables 9-8, 9-9, and 9-10). TPH-Dx was retained as a preliminary COPC only because no SLV is available.

Concentrations of total PCBs (as congeners and as Aroclors, when detected) exceeded SLVs in all random and targeted Forebay sediment samples (Tables 9-8, 9-9, and 9-10). The highest concentrations were observed along the north shore of Bradford Island and at Eagle Creek (Figure 9-14e). The sample along the north shore (P4) of the island was adjacent to where the equipment and contaminated sediment were removed between 2000 and 2007, although the observed concentration of 28.9 µg/kg was much lower than historical samples collected in the remediated areas. There is no known PCB source near Eagle Creek, although the state–run Cascade Salmon Hatchery is in this location. In any case, the PCBs detected at station P43 reflect limited contamination in a small area since PCBs were undetected (MDL of 1.7 µg/kg) at the adjacent station (P44, Figure 9-14e). Throughout the remainder of the Forebay, PCB concentrations in sediment ranged from 0.061 to 1.69 µg/kg and no apparent spatial pattern (Figure 9-14e).

9.6.2.3 Tissue

Tissue data from the random Forebay locations are summarized in Tables 6-9a (clam), 6-10a (crayfish), 6-11a (sculpin), 6-6a (smallmouth bass) and Appendix I, Tables I-8a and I-8b. Tissue data from the single targeted goose island station are summarized in Tables 6-13a and Appendix I, Tables I-9a and I-9b.

For analytes in which one or more tissue sample(s) exceeded SLVs (Tables 9-8 and 9-9), concentrations were plotted spatially on Figures 9-14a through 9-14g and 9-15a through 9-15g. For comparison, sediment data are also plotted on these figures, even if all of the sediment data were below the applicable sediment SLV for the analyte shown.

Concentrations of arsenic in tissue exceeded the tissue SLV for all media (clam, crayfish, sculpin, and smallmouth bass) at all locations (Figures 9-14a and 9-15a). However, crayfish was the only media for which arsenic concentrations in the Forebay were significantly higher than arsenic concentrations in the Reference Area (Table 8-2). As discussed in Section 8.2, arsenic concentrations in Forebay sediments and in all other tissue types were not statistically higher than Reference Area concentrations (Table 8-2). Furthermore, arsenic concentrations in sediment

were below the sediment SLV everywhere in the Forebay. The source of the arsenic is unknown, but does not appear to be site-related.

Although the Forebay sediment cadmium concentrations were not statistically higher than Reference Area concentrations (Table 8-2), cadmium concentrations in six individual sediment samples exceeded the SLV (Figure 9-14b). Cadmium concentrations in Forebay clams were statistically higher than in Reference Area clams (Table 8-2), and the concentrations exceeded the tissue SLV in all of the Forebay clam samples (Figure 9-14b). However, with the exception of two crayfish samples, the cadmium concentration was lower than the tissue SLV in all of the higher trophic-level samples (Figure 9-15b). Thus, although cadmium exceeded SLVs in the clam tissue, cadmium does not appear to be a concern in the sediment, nor does it appear to be a risk in higher trophic-level organisms.

Lead concentrations in all Forebay sediment samples were below the SLV and not statistically higher than the Reference Area concentrations. However, unlike the case for arsenic, lead concentrations were also below SLVs in all Forebay clam and smallmouth bass samples (Figures 9-14c and 9-15c). Selected Forebay samples of crayfish and sculpin did have lead concentrations which exceeded the SLV.

Mercury showed yet a different pattern. As with all metals, the Forebay mercury concentrations in sediment were not statistically higher than Reference Area concentrations (Table 8-2), although mercury concentrations slightly exceeded the SLV in five sediment samples (Figure 9-14d). Mercury concentrations in all of the Forebay clam and crayfish tissue samples were below the SLV (Figures 9-14d and 9-15d). In contrast, all of the sculpin and smallmouth bass samples had mercury concentrations exceeding the SLV (Figure 9-15d). The mercury concentrations in Forebay crayfish, sculpin, and smallmouth bass in the Forebay were all significantly higher than in the Reference Area (Table 8-2). The source of the mercury is unknown, but does not appear to be site-related.

B2EHP was detected in five of 23 sediment samples and all clam samples collected in the Forebay, but always at concentrations below the SLVs (Figure 9-14e), and at concentrations that were not significantly higher than in the Reference Area (Table 8-2). B2EHP concentrations above the SLV were measured in two crayfish samples and seven bass (Figure 9-15e). Bass was the only media for which concentrations of B2EHP were significantly higher in the Forebay than in the Reference Area. One other phthalate (butyl benzyl phthalate) was also detected above the SLV in one bass samples (Table 9-8). These observations may be consistent with B2EHP bioaccumulating in higher trophic-level organisms.

LPAHs did not exceed SLVs in any River media. However, five HPAHs were detected in one or more bass at concentrations exceeding the corresponding SLVs (Table 9-8). Benzo(a)pyrene was the only PAH detected above SLVs in crayfish (two samples only), and no PAHs exceeded SLVs in any of the other media (Table 9-8) (sculpin were not analyzed for SVOCs due to insufficient sample volumes). Since the eight bass in which benzo(a)pyrene concentrations exceeded the SLV included all bass in which any of the other HPAH concentrations exceeded the SLVs, this compound was plotted in Figures 9-14f and 9-15f to demonstrate the spatial pattern of HPAH SLV exceedances. As was the case for B2EHP, HPAH concentrations did not exceed SLVs for any sediment or clam samples (Figure 9-14f). One HPAH (benzo(a)pyrene) exceeded the SLV in two crayfish samples, and one or more HPAHs exceeded SLVs in eight bass samples (Figure 9-15f). The three bass with the highest benzo(a)pyrene concentrations were caught along the north

shore and tip of Bradford Island. These observations may be consistent with HPAHs bioaccumulating in higher trophic-level organisms, even though concentrations of PAHs in Forebay sediment were not significantly higher than in the Reference Area (Table 8-2).

Concentrations of total PCBs (as congeners) exceeded SLVs for almost all tissue samples (Figures 9-14f and 9-15f). The highest observed total PCB (as congeners) concentration in clams (312 µg/kg) was from a sample collected at station P4 on the north shore of Bradford Island. Somewhat lower clam tissue concentrations (51.5 to 95.1 µg/kg) were measured at stations around the tip and southern shore of the island (Figure 9-14e). Throughout the remainder of the Forebay, clam total PCB concentrations were within a remarkably narrow range (21.4 to 34.0 µg/kg) – and within the range of concentrations (26.8 to 34.4 µg/kg) measured in the River Reference Area. This suggests that the clams (short-lived benthic organisms reflecting a very localized exposure area) were acquiring somewhat higher body burdens of PCBs from the small quantity of residual PCBs in sediments adjacent to the historical source area. The uniform clam tissue concentrations throughout the remainder of the Forebay and River Reference Area provides strong evidence that there are no significant residual PCB sources in other parts of the Forebay.

As would be expected via bioaccumulation, average tissue concentrations of total PCBs increased in higher trophic-level organisms. Total PCBs (as congeners) ranged from 0.54 to 42.7 µg/kg in crayfish, 8.15 to 4,780 µg/kg in sculpin, and 32.2 to 26,500 µg/kg in smallmouth bass (Figure 9-15e).

As with the clams, the crayfish and sculpin with the highest total PCB concentrations were all located along the shore of Bradford Island. The three crayfish samples with the highest PCB concentrations (P6-CF with 42.7 µg/kg, P5-CF with 16.9 µg/kg, and P4-CF with 16.8 µg/kg) were along the north shore and eastern tip of the island (Figure 9-15e). The two samples with the next highest concentrations (P7-CF with 12.4 µg/kg and P8-CF with 3.13 µg/kg) were along the south shore of the island; all other crayfish samples had total PCB concentrations less than 1.5 µg/kg.

Similarly, the highest concentration of total PCBs observed in sculpin was in sample SF-3 (4,780 µg/kg) at the tip of Bradford Island (Figure 9-15e). The next three highest total PCB concentrations measured in sculpin (915 µg/kg at SF-4, 559 µg/kg at SF-5, and 141 µg/kg at SF-6) were at progressively greater distances from the historical source area, along the southern shore of the island (Figure 9-15e). The lowest total PCB concentration in sculpin was measured in the targeted sample from Goose Island Slough.

The spatial distribution of total PCB concentrations in Smallmouth Bass (Figure 9-15e) was much more variable. Some of the bass with the highest concentrations caught adjacent to bass with the lowest concentrations. The highest total PCB concentration was measured in a bass caught off the tip of Bradford Island; the second-highest concentration was measured in a bass caught in the Goose Island Slough (Figure 9-15e). Other individual bass caught simultaneously in the slough have total PCB concentrations less than or comparable to those observed in the River Reference Area (22.3-499 µg/kg; see Appendix L, Table L-7). This lack of a spatial pattern is consistent with bass migrating into the Goose Island Slough to breed, taking with them a wide range of PCB body burdens picked up from various locations in the Forebay.

It is also important to remember that the Forebay bass were collected in 2006, before the 2007 sediment removal. Some of the older bass are estimated to have been up to 10 years old in 2006,

meaning that they were exposed to conditions before the equipment was even removed (URS 2009k) There was a huge variation in tissue PCB concentration, reflecting a great deal of variability in exposure. However, there was no correlation between PCB concentration and either length (a proxy for fish age) or the location where the fish were caught. The implications of these observations are discussed in detail in the HHRA and ERA (Chapters 11 and 12)

9.6.3 Cross-media Patterns in PCB Congener Distributions

The PCB congener analytical method used to analyze all of the recent data from the River OU provides concentrations of all 209 congeners (with the recognition that some of these congeners are coeluting so that only the total concentration of the coeluting species), it can be a valuable tool for the identification of potential PCB sources. PCBs from different sources may have different patterns of relative abundances of the various PCB congeners. However, the patterns may be altered in environmental media due to mixing of PCBs from multiple sources, preferential biological uptake or preferential bioaccumulation of certain congeners, chemical or biological degradation, or other mechanisms.

To see what information the PCB congener distribution may provide regarding PCBs observed in various media analyzed in this study, Figures 9-16a through 9-16e (Forebay) and Figures 9-17a through 9-17e (Reference Area) were prepared showing histograms of PCB congener relative abundance. Different color segments on these figures show each detected PCB congener (or set of coeluting congeners) as a percentage of total PCB congener concentration in each sample. The total height of each bar is always 100%, but the percentages of component congeners vary from sample to sample. The total PCB (as congener) concentrations is listed below each sample name and the samples within each figure or sorted from highest to lowest total PCB concentration. Forebay samples are plotted separately from Reference Area samples, and different media are shown on different figures.

The following PCB congener patterns were noted:

- Of the 209 possible PCB congeners, approximately 16 PCB congener groups constituted 60 to 70% of the total PCB congener load in sediment in both the Reference Area and the Forebay. The same 16 PCB congener groups constituted approximately 80% the PCB congener load in clams and crayfish and approximately 70% of the PCB congener load in sculpin and bass.
- The most abundant PCB congener at a majority of the stations was PCB 11. This PCB congener constituted from approximately 7 to 27% of the total PCB congener burden, and contributes a larger percentage to samples with lower total PCB concentrations. This is consistent with the results of other regional studies have noted that airborne PCBs in the Willamette airshed have contributed to the ubiquitous occurrence of PCBs in sediments and that PCB 11 is one of the indicator PCB congeners for evidence of airborne deposition (Hope 2007, 2008). PCB 11 has also been found in water and air in urban environments (Hu et al. 2008, Du et al. 2009, Rodenburg et al. 2010), the great lakes watershed (Basu et al. 2009), and even the polar regions (Choi et al. 2008). Part of the reason it is so ubiquitous may be that it is not derived by Aroclor mixtures, but is instead found in unregulated paints and pigments (Fraser 2010, Hu and Hornbuckle 2010, Rodenburg et al. 2010).
- PCB 118, another ubiquitous PCB congener in the Willamette airshed, was also observed in all river media (surface water, sediment, clam, crayfish, sculpin, and smallmouth bass).

Therefore, risk from PCBs in the River OU likely includes both site-related sources, and non-site related sources, including those from upstream as well as from the ubiquitous presence of PCBs in the Willamette airshed.

- The homologue groups showing the greatest degree of accumulation are primarily the pentachloro- and hexachlorobiphenyls, with a few additional tetrachloro- and heptachlorobiphenyls. This pattern is generally consistent with the environmental behavior of PCBs, whereby the lower chlorinated homologues are relatively more soluble and less persistent and the higher chlorinated homologues tend to be less soluble, more persistent, and more available for biological uptake.
- Four dioxin-like PCB congeners (PCB 105, 118, 156, and 157) are among the 30 most abundant PCB congener groups in sediment. The dioxin-like PCB congeners make up approximately 10 to 15% of the total PCB congener burden in sediments. Only two dioxin-like PCB congeners were relatively abundant in tissue samples (PCB 105 and 118) and constitute approximately 10 to 20% of the overall PCB congener burden in tissues.
- Relative to the Reference Area, Forebay sediments appear to contain higher concentrations of four sets of PCB congeners (93+95+98+100+102, 86+87+97+108+119+125, 52, and 61+70+74+76). Although none of these groups includes dioxin-like PCB congeners, these co-eluting groups correspond to the pentachloro- and tetrachlorobiphenyl groups.

In summary, the same sub-set of about 30 PCB congeners constituted the majority of the PCB congener load in both Forebay and Reference Area sediments and that an even smaller sub-set of PCB congeners (the 16 dominant PCB congeners of the 30 observed in sediments) was noted in the Forebay and Reference Area tissues.

9.6.4 Correlation Between PCBs, TOC, and Fine-Grained Sediment

This section describes a correlation analysis between three sediment parameters: total PCB congener concentration (represented as sum of 209 congeners' concentrations), TOC, and percent fines (represented as sum of percent clay and percent silt). Organic contaminants such as PCBs are generally expected to be associated with fine-grained sediments or the TOC present in sediments. The objective of this statistical evaluation was to confirm that this was, indeed the case at this site and explore possible trends or patterns in the data which may further support site characterization and remedial investigation.

In order to examine potential correlation over the entire range of observed PCB concentrations, the Reference Area and Forebay data sediment samples were combined into a single data set. The bivariate relationships between these three parameters were examined using the non-parametric Kendall-Theil robust line and Kendall's Tau correlation coefficient, described in Helsel and Hirsch (2002). One Forebay location, P04, initially appeared to be an outlier; however, the nonparametric methods used to calculated correlation coefficients were not sensitive to the presence of outliers, and hence, the data from this location were included in all calculations.

The Kendall-Theil robust line method was used to test for any monotonic, not just linear, dependence of each pair of variables. This method did not depend on the normality of residuals for validity of significance tests, as in ordinary linear regression. The Theil slope estimate was computed by comparing each data pair to all others in a pair wise fashion, and the median of all

possible pair wise slopes was taken as the nonparametric slope estimate. This line was closely related to Kendall's Tau correlation coefficient, in that the significance of the test for H_0: slope = 0 was identical to the test for H_0: Tau = 0.

The results of this correlation analysis are presented in Figure 9-18. The bottom panel presents TOC versus percent fines. The middle panel presents total PCB congeners versus TOC. And the top panel presents total PCB congeners versus percent fines. The Kendall-Theil robust line equation, the Kendall's Tau correlation coefficient, and the *p*-value associated with the test of significance are shown in each panel. For better scaling of the scatter plots, the aforementioned Forebay location (P04) is not shown in the middle and top panels, but this data point was used in the calculation.

As expected, for TOC versus percent fines, the Kendall's Tau correlation coefficient was 0.530, which suggested a strong monotonic relationship. For total PCB congeners versus TOC and total PCB congeners versus percent fines, the Kendall's Tau correlation coefficients were 0.318 and 0.356 respectively, an indication of a moderate monotonic relationship or positive association (i.e., the higher the TOC or percent fines, the higher the total PCB congener concentrations, or vice versa). The *p*-values associated with all three tests of significance were below 0.01, which indicated that the slope or the Tau was significantly different from (above) zero.

Thus, TOC is strongly correlated with percent fines. Higher TOC concentrations can be reliably predicted by smaller grain size distribution and therefore these two variables are not independent. Total PCBs as congeners are moderately correlated with the other two variables – sediment with higher TOC and percent fines typically have higher total PCB concentrations.

9.6.5 Trends Through Time

Figure 9-19 summarizes the sequence of removal actions and sample collection in the Forebay. Above the timeline, maximum concentrations of total PCBs measured in sediment during five different investigations are plotted on a logarithmic scale. As can be seen from this graph, the removal of the in-water sources of contamination has dramatically reduced both the maximum measured sediment concentrations along the north shore of Bradford Island.

Prior to 2007, data collection efforts in the river were focused on locating areas of potential sediment contamination, not documenting the distribution of sediment concentrations. Additionally, different sample collection and analytical methods were used. Therefore, it is not appropriate to compare the distribution of PCB concentrations measured during each sampling event. Instead, the highest observed sediment concentrations along the north shore of Bradford Island are presented to show the decrease in the "worst-case" concentrations on through time.

In 2001, the maximum total PCB concentration of 15 sediment samples was 23,900 µg/kg (URS 2002b). During February/March 2002, thirty-two tons of waste, including PCB-containing electrical equipment and collocated sediment were removed from three debris piles on the north side of Bradford Island. As part of this removal, approximately 100 sediment samples were collected to delineate the extent of impacted sediment. The highest total PCB concentration for sediments measured in 2003 was 690,000 µg/kg (URS 2003c and URS 2004c). Three years later, in 2006, divers collected sediment samples as close as possible to the locations of two of the 2003 samples with the highest total PCB concentrations. When resampled, the stations that had total PCB concentrations of 690,000 µg/kg and 2,400 µg/kg in 2003, had concentrations of only 440 µg/kg and 160-2,100 µg/kg, respectively, in 2006 (URS 2006b). The following year, five

pre-removal sediment samples collected in September 2007 from the areas that were later dredged had total PCB concentrations ranging from 13 to 133 µg/kg (URS 2008d).

Overall, total PCBs decreased by two to four orders of magnitude in the sediments on the north shore of Bradford Island between 2003 and 2007 (Figure 9-19). In October 2007, during the dredging removal action, 63 tons of sediment was removed from the north side of Bradford Island (HAI 2007). Following this removal a sample collected along the north shore of Bradford Island in an area that was not dredged (station P04) contained only 27.9 µg/kg total PCBs.

Declining total PCB concentrations were also observed in the Forebay crayfish collected from the north shore of Bradford Island. Crayfish composite samples collected during May 2001, in the vicinity of Debris Piles 1 and 2, had total PCB concentrations ranging from 2,670 to 75,600 µg/kg (URS 2002a,b). The composite crayfish sample with the highest total PCB concentration (75,600 µg/kg) was collected from former Debris Pile 1 and is the highest measured total PCB concentration for any tissue sample, including smallmouth bass, collected from the Forebay. Crayfish composite samples collected in February 2008 from the north shore of Bradford Island (stations 4 and 5) had total PCB concentrations three to four orders of magnitude lower (16.8 to 16.9 µg/kg) than those collected in 2001 (URS 2009i). The clams collected from 2001 to 2008 show a similar natural attenuation trend of decreasing total PCB concentration.

As described in the Goose Island Slough Data Gap Summary Report (URS 2009k), similar reductions in total PCB concentrations were observed in other areas of the Forebay. For example, a composite sample of three crayfish sample was collected near the western tip of Goose Island in May of 2001, prior to the removal of the contaminated equipment or sediment. The total PCB concentration in this sample was 268 µg/kg. Crayfish samples collected in 2008 and 2009, in the vicinity of Goose Island, had two to three orders of magnitude lower concentrations of PCBs (0.578 to 0.960 µg/kg).

Recognition of this observed natural attenuation, and the timing of equipment and sediment removals relative to Forebay sample collection is important for understanding the relatively high concentrations of total PCBs measured in the Forebay smallmouth bass. Based on age to length relationships for smallmouth bass captured in Lake Ontario, New York and in the Columbia River (Adams et al. 1999, Henderson and Foster 1956), the approximate ages of the 19 smallmouth bass collected from the Forebay in 2006 range from 4 to 10 years (URS 2008c). Therefore, it is reasonable to assume that all of the smallmouth bass sampled in 2006 were spawned in or before 2002 – the year that the equipment was removed from the Forebay (Figure 9-19).

Although most of the Forebay smallmouth bass were caught in the Goose Island Slough, the slough is unlikely to represent their home pool. Instead, as discussed in the Goose Island Slough Data Gap Summary Report (URS 2009k), bass are believed to have migrated into the Slough to spawn, from their home pools in other areas of the Forebay. The 0.45 kilometers (km) distance from Bradford Island to the Goose Island slough is only slightly larger than the largest weekly recorded movement of 0.37 km observed in the Huron River (Beam 1990), and is well within the observed migratory distances traveled by smallmouth bass during the spawning season. Studies of migratory patterns of smallmouth bass in the Snake River in Idaho showed that fish found outside their home pool, in spring, traveled distances up to 1.2 km (Munther 1970). Radio-tagged bass in the Columbia River have been recorded traveling distance as much as 63 km (Montgomery et al. 1980). While long distance travel for smallmouth bass is uncommon, it is

entirely reasonable to assume the smallmouth bass population living near Bradford Island would travel the short distance (0.45 km) to the slough, for the purposes of preferential spawning habitat.

It is reasonable to assume that the Forebay smallmouth bass sampled in 2006 were exposed to the sediments and were consuming lower trophic level organisms near the PCB-containing equipment on the northern side of Bradford Island prior to the equipment removal in 2002. And, since the second removal of contaminated sediments did not occur until 2007, all of the smallmouth bass caught in 2006 could have spent their entire lifespan exposed to the higher concentration sediments on the north shore of Bradford Island prior to the sediment removal (see Figure 9-19).

Therefore, it is highly probable the PCB concentrations observed in the smallmouth bass collected from the are related to a historical body burden associated with the contaminated equipment and sediments which have since been removed from the northern side of Bradford Island. Long term monitoring of the Forebay smallmouth bass population, will likely show decreases in PCB concentrations, as similar trends have already been observed for sediments and lower trophic level media.

10.0 FATE AND TRANSPORT OF CONTAMINANTS

This section describes the fate and transport of contamination associated with Bradford Island releases at the Upland OU and River OU.

10.1 Upland OU Fate and Transport of Contaminants

The fate and transport of contaminants is described below for each of the four Upland OU AOPCs. The sources and nature of releases of contaminants to the environment are summarized, followed by a description of potential or confirmed mechanisms for transport of contaminants from the AOPCs. The understanding of the fate and transport at each AOPC is based on knowledge of historical and ongoing waste management practices and activities, observations of existing site conditions that affect fate and transport, analytical data for soil, soil gas, groundwater, seep water, and surface water, and knowledge of the behavior of chemicals in the environment.

10.1.1 Landfill AOPC

The presence of contamination at the Landfill AOPC resulted from use of the area to manage, store, and dispose of waste materials. In addition to the placement of wastes within the Landfill AOPC, other historical activities included pesticide/herbicide mixing and rinsing activities, and historical storage areas. Discrete source areas have not been identified within the Landfill AOPC. Rather, the type and magnitude of contamination within the Landfill AOPC is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the Landfill AOPC.

Inorganic and organic contaminants at the Landfill AOPC were initially released to surface and/or subsurface soils. Contaminants that adsorb strongly to soil (e.g., PCBs and PAHs) and are not readily soluble or volatile have likely remained at their point of release. The only potential transport mechanism for insoluble/non-volatile contaminants is to physically move the soil by surface erosion and/or mass wasting of soil. The surface of the landfill itself shows minimal evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable and there is minimal potential for off-site migration of contaminated soil by surface erosion. Around the perimeter of the Landfill AOPC, the potential for mass wasting of soil into the Columbia River appears low. However, metals, pesticides, PCBs, PAHs, and SVOCs were detected in the Landfill AOPC perimeter soil samples at concentrations exceeding the sediment SLVs. There is an ongoing but low potential for these contaminants to be transported off site to the river via mass wasting.

Volatile soil contaminants (e.g., VOCs and SVOCs) can be released to air from surface and subsurface soils. Dust generation can also release volatile and non-volatile soil contaminants in particulate form to air. VOCs and SVOCs were present in surface and subsurface soils at the Landfill AOPC, and therefore there is a potential for volatilization of these chemicals to outdoor air at the Landfill AOPC. However, since the Landfill AOPC is not occupied by site works, and the ambient conditions are typically windy, the potential for exposure of site workers to volatile constituents in air at levels of concern is extremely low, primarily due to the dispersion of these constituents in air. Since the Landfill surface is well vegetated and vehicles or heavy equipment are not operated on the Landfill surface, the potential for contaminant migration in dust is very low.

Contaminants that may have been initially released as a liquid phase (e.g., PCB-containing oils in buried electrical equipment) can potentially infiltrate into, and migrate through soil as a liquid phase. The extent to which the liquid phase would migrate through soil is in part a function of the release volume and the tendency of the liquid to adsorb to soil. Small releases of liquids that adsorb strongly to soil (e.g., PCB-containing oils) would likely not migrate far from the point of release. Subsurface investigations at the Landfill AOPC have not identified evidence of contaminants present in a liquid phase. In addition, contaminant concentrations measured in soil, groundwater, and seep water at the Landfill AOPC were well below concentrations that would be expected if contaminants were present in a concentrated, liquid phase. Therefore, it is very unlikely that off-site transport of contaminants in soil is an ongoing process at the Landfill AOPC.

A final potential mechanism for off-site transport of contaminants at the Landfill AOPC is leaching of contaminants from buried debris and/or contaminated soil to groundwater, and potential transport to surface water. The degree to which a contaminant may leach to water is mainly a function of its solubility in water although there are other factors that also affect its solubility. Few contaminants are completely insoluble in water and most contaminants are soluble to a lesser or greater degree. Leaching of contaminants from surface soil to surface water is a potential mechanism at the Landfill AOPC. Surface runoff has been observed originating at the base of the hill south of the Landfill. However, this runoff infiltrates into the ground before reaching the river, and no other evidence of direct discharge of surface water to the river has been observed at the Landfill AOPC.

Groundwater analytical data confirm that most contaminants detected in surface and subsurface soils were also detected in groundwater. The mechanism for this leaching is likely a combination of leaching directly to infiltrating precipitation in unsaturated soil and leaching directly to groundwater where Landfill wastes are saturated by the seasonal high water table. Seep water analytical data indicate that metals, DRO, and selected VOCs have migrated in groundwater to seeps at concentrations exceeding the surface water SLVs. However, seep water is rapidly diluted upon discharge to the river, as demonstrated by the fact that DRO and VOCs were not detected in concurrent samples of adjacent surface water. SVOCs also appear to have migrated to the seeps but at concentrations below the surface water SLVs. Butyltins, herbicides, pesticides, and PAHs were detected in groundwater but not seep water, indicating that they may be leaching to groundwater but are not migrating to the river. PCBs were not detected in groundwater or seep water, consistent with the very low solubility of PCBs in water.

In summary, the primary mechanism for off-site transport of contaminants from the Landfill AOPC appears to be leaching of contaminants from buried debris and/or contaminated soil to groundwater, and discharge of contaminants in groundwater zone to the river via seeps. The COPCs to this migration pathway are metals, TPHs, and VOCs. There is also a low potential for metals, pesticides, PCBs, PAHs, and SVOCs in soil to migrate to the river via mass wasting of soil.

10.1.2 Sandblast Area AOPC

Contamination at the Sandblast Area AOPC resulted from a variety of historical and ongoing uses that include equipment storage and management, as well as storage and disposal of various hazardous materials and wastes. The type and magnitude of contamination is variable, consistent with the variable hazardous substance and waste management, storage, and disposal practices

that occurred at the various subareas within the Sandblast Area AOPC. Some contaminants are widespread in soil and groundwater and are not associated with a discrete source within the Sandblast Area AOPC. Other contaminants appear to be specifically associated with the sandblast grit disposal area, the equipment laydown area, and an inferred VOC release from a storage tank previously located where the HMSA is currently located.

Inorganic and organic contaminants at the Sandblast Area AOPC were initially released to surface and/or subsurface soils. Throughout much of the Sandblast Area AOPC, contaminants that adsorb strongly to soil and are not readily soluble or volatile have likely remained at their point of release. However, observation of the site conditions confirm that soil erosion is a historical and ongoing process that has mobilized and transported soil within portions of the Sandblast Area AOPC. Soil erosion is the result of stormwater runoff from impervious surfaces, as well as direct precipitation onto and runoff from soils recently disturbed by excavation and filling activities. Stormwater from the northwest portion of the Sandblast Area AOPC drains to four catch basins; two stormwater pipe outfalls convey runoff from the catch basins to the Columbia River. The catch basin drainage areas include areas where soil erosion and transport is documented. Metals, PCBs, TPH, butyltins, pesticides, SVOCs, PAHs, and VOCs were detected in erodible soil, and constituents of each of these analytical groups, except TPH and VOCs, exceeded sediment SLVs. Metals, butyltins, PCBs, and TPHs were detected in soil along the stormwater flow path to CB-1, and/or in soil immediately adjacent to CB-1. With the exception of the stormwater flow to CB-1, no other evidence of direct discharge of soil in stormwater to the river has been observed at the Sandblast Area AOPC.

Soil gas analytical data from soil borings confirm that VOCs were present in soil gas at, and downgradient of, the inferred PCE source area at the current HMSA. VOC concentrations exceeded soil gas SLVs but not at locations occupied by site workers. Thus, VOCs are potentially being released to air, but not likely at concentrations of concern to on-site workers. Volatile and non-volatile contaminants were present in surface soils at locations that are barren and/or experience infrequent vehicle traffic. There is a potential for transport of volatile and non-volatile soil contaminants in dust, but this transport mechanism is likely very minor. To the extent that soil adheres to vehicle tires in the Sandblast Area AOPC, there is also a potential for transport of contaminants along road ways within the Sandblast Area AOPC and elsewhere at Bonneville Dam, although this mechanism is likely minor due to the minimal vehicle traffic at the Sandblast Area AOPC.

A storage tank was reportedly present at the location of the current HMSA prior to its construction. VOC concentrations in soil, soil gas, and groundwater indicate that a PCE release occurred at this location, and the former storage tank is the inferred source of the release. Very high concentrations of PCE and TCE were reported in soil adjacent to the current HMSA; elsewhere, VOC concentrations were much lower. Evidence of liquid phase contamination was not observed in soil borings or monitoring wells downgradient of the current HMSA. Groundwater analytical data demonstrate that VOC concentrations at the inferred source area are decreasing over time. The analytical data and soil boring/monitoring well observations suggest that liquid phase contamination may have been present in soil at or in the vicinity of the former storage tank at the time of the release. But it appears unlikely that significant migration of liquid phase contamination occured. Evidence of liquid phase contamination has not been encountered elsewhere at the Sandblast Area AOPC.

Leaching of contaminants from surface soil to surface water is a potential mechanism at the Sandblast Area AOPC. As described above, metals, PCBs, TPH, butyltins, pesticides, SVOCs, PAHs, and VOCs have been detected in soil within the drainage area of the four stormwater catch basins. Since many of these contaminants are soluble in water, off-site transport of dissolved-phase contaminants in stormwater may be occurring at the Sandblast Area AOPC.

Groundwater analytical data confirm that most contaminants detected in surface and subsurface soils have leached to groundwater. Metals, butyltins, pesticides, PAHs, TPHs, SVOCs, and VOCs were detected in groundwater. PCBs were not detected in groundwater, consistent with the very low solubility of PCBs in water. Concentrations of metals, PAHs, and VOCs in groundwater exceeded their surface water SLVs, including at locations immediately adjacent to the river, indicating that these contaminants may be migrating to the river at concentrations of potential concern. Butyltin, pesticide, TPH, and SVOC concentrations did not exceed SLVs. Seeps have not been observed along the river bank at the Sandblast Area AOPC, but groundwater is assumed to discharge to the river as base flow.

In summary, the primary mechanisms for off-site transport of contaminants from the Sandblast Area AOPC appear to be soil erosion and transport in stormwater to the river, and leaching of contaminants from contaminated soil to groundwater followed by discharge of groundwater to the river via base flow. The potential contaminants of concern to one or both of these transport mechanisms include metals, butyltins, pesticides, PCBs, PAHs, TPH, SVOCs, and VOCs. There is also a potential for off-site migration of soluble contaminants in stormwater, but samples of stormwater have not been collected and analyzed to confirm this.

10.1.3 Pistol Range AOPC

Use of the Pistol Range AOPC as a firing range resulted in the contamination of soil with lead and zinc. The highest lead concentrations in soil are at and behind the backstop, and are likely associated with bullet fragments that remain in the soil. In lagoon sediment adjacent to the Pistol Range AOPC, zinc concentrations exceeded the sediment SLV, and were also higher than the maximum concentration of zinc detected elsewhere in Forebay sediments. The analytical data indicate that historically, when the pistol range was in use, off-site migration of metals to the river may have occurred as a result of soil erosion and/or soluble transport in stormwater. Currently, however, the Pistol Range AOPC is well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition. Similarly, since the Pistol Range AOPC is well vegetated and vehicles or heavy equipment are not operated at the site, the potential for migration of metals in dust is very low.

Total concentrations of copper, lead, nickel, and zinc, and dissolved concentrations of copper, nickel, and zinc were detected in groundwater at the Pistol Range AOPC, although no detected concentrations exceeded the water SLVs. Although the soil conditions beneath the Pistol Range AOPC accommodate very little groundwater (most of the holes drilled were dry), the analytical data from the two samples collected suggest that metals have leached to groundwater to a limited extent. The discharge of this groundwater to the river as baseflow may provide a mechanism for transport of metals to the river, but not at concentrations of potential concern.

In summary, minor leaching to groundwater followed by discharge of groundwater to the river via base flow is the only (very limited) mechanism of transport of contaminants from the Pistol Range AOPC to the river.

10.1.4 Bulb Slope AOPC

Contamination at the Bulb Slope AOPC resulted from placement of glass and electrical light bulb debris directly onto a steep slope between the landfill access road and the Columbia River. Lead, mercury, PCBs, and TPH have been detected in surface soils at the Bulb Slope AOPC. The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface runoff or overland flow to the river. Wave erosion at the base of the slope has resulted in mass wasting of soil which appears to be a potential mechanism for transport of debris and/or contaminated soil into the river. Owing to the well vegetated nature of the Bulb Slope AOPC, the potential for migration of contaminants in dust is very low.

There is a low potential for metals and TPHs to leach from the soil into groundwater and discharge to the river as base flow. Given the thin soil layer and small footprint of the Bulb Slope AOPC, and the fact that it is well-vegetated with trees and shrubs, leaching to groundwater is likely an insignificant transport mechanism. PCBs have a very low solubility in water and are unlikely to leach to groundwater or surface water.

In summary, mass wasting of soil at the base of the Bulb Slope AOPC appears to be the primary mechanism for transport of contaminants to the river.

10.2 River OU Fate and Transport of Contaminants

Contamination in the River OU resulted from electrical equipment debris which were historically disposed of directly in the River on the north side of Bradford Island. The electrical debris contaminated the surrounding sediment, primarily with PCBs. The electrical equipment debris were removed in 2000 and 2002 (URS 2002b) and the majority of the associated PCB-contaminated sediment was removed in 2007 (URS 2008e,f,g). Residual contaminated sediment, as well as historically contaminated biota (e.g., fish and shellfish) may currently be sources of contamination. Transport of contaminants from the Upland OU, discussed above, may also be a current and/or historical source of contamination to the River OU.

During the post-removal sampling in 2008, PCBs, PAHs, metals, and TPH were detected in Forebay sediment. The same contaminants were also detected in Forebay surface water samples. Contaminants are exchanged between the surface water and sediment via sorption and dissolution. The partitioning of individual contaminants between the solid (sediment) and liquid (surface water) phases depends on their solubility. Generally, hydrophobic contaminants, such as PCBs, are strongly bound to the sediment, and tend to be concentrated in areas of fine-grained sediment with relatively high TOC. The Columbia River is a dynamic environment in which sediment is constantly being redistributed within the Forebay through human and natural processes. However, numerical modeling and direct sampling contain the extent of contamination to be between the upstream end of Goose Island and the Bonneville Dam.

11.0 HUMAN HEALTH RISK ASSESSMENT

This section presents the methodology and findings of the HHRA that was performed for the Upland and River OUs in support of the RI. The HHRA process is similar for the River and Upland OUs, as described in the RI/FS MP (URS 2007a).

11.1 Purpose of HHRA

The overall purpose of the HHRA is to assist the USACE with achieving the management goals for the Upland and River OUs in a manner that complies with federal USEPA and state (DEQ) regulatory guidance. Based on the results of the risk assessment, additional evaluation, risk management or response actions may be needed to meet the management goals for these OUs.

HHRA for Upland OU

As listed in the RI/FS MP (URS 2007a), the management goals for the Upland OU that are relevant to the HHRA are:

1. Continued use of Bradford Island for occupational/ industrial uses in support of operations at Bonneville Lock and Dam
2. Protection of the health of on-site workers and visitors who may be present at the Upland OU
3. Protection of the River OU from upland sources of contamination

The objectives of the HHRA for the Upland OU and AOPCs have been developed on the basis of the management goals and are to:

1. Evaluate if risks from COPCs to human receptors exceed unacceptable levels at any of the Upland AOPCs or the Upland OU overall and,
2. Evaluate if the COIs in upland soils and groundwater can migrate into the River OU at levels of potential concern for receptors in the River OU

HHRA for River OU

The USACE's management goals for the River OU that are relevant to the HHRA are:

1. Continued safe maintenance and operations of the Bonneville Lock and Dam complex
2. Support of and protection of the health and livelihood of people who may utilize the area for contact recreation, fishing recreation, or subsistence fishing purposes
3. Support of the beneficial uses of the Columbia River in this segment including the protection of anadromous and resident fish species utilizing the area

The Forebay is located downstream of several other potential sources of COIs that may overlap with the COIs for the River OU. Since one of the goals of the baseline risk assessment is to evaluate risks due to site-related COIs, the objectives of the risk assessment for the River OU are twofold:

1. Evaluate whether COIs in the Forebay should be identified as COPCs based on comparison with both risk screening values and upstream (reference) conditions
2. Evaluate whether risks to human receptors due to COPCs are at unacceptable levels

11.1.1 Scope of HHRA

According to USEPA and DEQ risk assessment guidance for human health, (DEQ 2000, 2003, 2010b; USEPA 1989), the HHRA process consists of a two-step process, the problem formulation, followed, if necessary, by the baseline risk assessment. The process begins with compiling information on the COIs. COIs are defined by DEQ as chemicals that are present or may be present at a site that have not been screened against any criteria (DEQ 2001). The COIs listed in the Appendix M tables represent chemicals detected at a frequency of 5% or more when 20 or more samples were available. When less than 20 samples were available, frequency of detection was not a consideration and this criterion was not used. Additionally, metals were also compared to Reference values and only those that were statistically greater than Reference, were included as COIs. Finally, if PCE or TCE were selected as COPCs, their degradation products were listed, even if they were not detected. The problem formulation step is used to narrow down the COIs to a smaller list of COPCs that warrant additional risk assessment or risk management actions. The baseline risk assessment is then performed to further narrow down the COPCs to a final list of chemicals of concern (COCs) for development of remedial action goals.

Problem formulation represents the first risk-based evaluation of all the relevant information and data pertaining to a site. By considering all the site information, current and likely future uses of land and water, and going through a comprehensive and exhaustive COPC selection process, the problem formulation process yields findings and conclusions that provide a solid basis for further decision-making. It provides screening-level estimates of carcinogenic risk and non-cancer hazards for the identified COPCs. The evaluation also allows for the identification and prioritization of the COPCs with regard to those which are most likely to be significant contributors to risk and will merit the most attention in terms of remedial action or further risk assessment. Similarly, if no COPCs are identified, the problem formulation process provides a strong foundation to base a decision of NFA.

The scope of the current HHRAs for the Upland and River OU is limited to the problem formulation phase of the HHRA. The problem formulation includes all four AOPCs in the Upland OU and the entire River OU. All the media that are relevant to human health exposure under current and reasonably likely future site conditions for which data have been collected (soil, soil gas, groundwater, sediment, surface water, tissue) are included in the evaluation.

11.1.2 Regulatory Framework

To achieve the objectives mentioned above, the steps that are used to conduct the problem formulation for the HHRA are based on USEPA and DEQ guidance (USEPA 1989; DEQ 2000, 2003, 2010b). Since DEQ is reviewing the RI/ FS, DEQ guidance was followed regarding the nature of the risk assessment process and the format and presentation of results. DEQ risk assessment protocols can be found in OAR Section 340-122-0084.

The guidance documents used in the performance of the HHRA include:

- Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites (DEQ 1998a)
- Final Guidance, Consideration of Land Use in Environmental Remedial Actions (DEQ 1998b)

- Guidance for Conduct of Deterministic HHRAs, Final (DEQ 2000)
- Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites (DEQ 2003, Updated 2009)
- Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment, Final (DEQ 2007)
- HHRA Guidance, Updated October 2010 (DEQ 2010b)
- Superfund Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Final (USEPA 1989)
- Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual. Part B, Development of Risk-Based Preliminary Remediation Goals, Interim (USEPA 1991)
- Guidance for Data Usability in Risk Assessment (USEPA 1992)
- Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites (USEPA 2002a)
- Calculating UCLs for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002b)
- Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), Draft (USEPA 2002c)
- Human Health Toxicity Values in Superfund Risk Assessments (USEPA 2003a)
- User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings, Draft (USEPA 2004)
- Regional Screening Levels (RSLs) and User's Guide (USEPA 2010)

Based on the guidance listed above, the problem formulation phase for the HHRA for the Upland and River OUs includes the following elements, as defined by DEQ (2000, 2010b):

- Review of existing site information
- Land and water use determination
- Definition of data quality objectives
- Determination of the nature and extent of contamination
- Identification of potentially exposed populations
- Definition of exposure scenarios and exposure routes
- Contaminant screening procedures
- Development of a CEM
- Discussion of uncertainties

Much of the initial review of site information and identification of exposed populations, and development of preliminary CEMs were completed in the RI/FS MP (URS 2007a) for both the

Upland and River OUs. These elements are further refined in the current evaluation based on review of newly collected data and closing of previously identified data gaps.

Based on earlier discussions with DEQ and as outlined in the RI/FS MP, 95% UCL values are used to represent site concentrations of COIs when the sample size is sufficient. The 95% UCL is based on USEPA recommendations and is consistent with the USACE's desire to maintain compatibility with the CERCLA process. It is slightly different from DEQ's recommendation to use the 90% UCL. Since use of the 95% UCL will not lead to underestimation of risk when compared to the 90% UCL, the TAG agreed that representation of the 95% UCL is acceptable.

An additional difference between USEPA and DEQ guidance is the evaluation of the human milk ingestion pathway for infants for bioaccumulative chemicals. This pathway is included in DEQ's recently issued HHRA guidance (DEQ 2010b) but does not include pre-calculated risk-based screening concentrations. At the federal level, no final guidance or risk-based screening levels are available for this pathway. Therefore, this pathway is considered on a qualitative basis in this problem formulation phase of the HHRA.

11.1.3 Acceptable Risk Levels

For human health evaluations, chemicals are typically evaluated on the basis of whether they are considered to be carcinogenic or non-carcinogenic. The risks associated with carcinogenic chemicals are expressed as a probability of an exposed individual developing cancer over a lifetime of exposure for a particular receptor and pathway. The probability is expressed as excess lifetime cancer risk (ELCR). The risks associated with exposure to multiple chemicals within a single medium or multiple media are estimated by adding the individual ELCR probabilities and expressed as cumulative ELCR, typically expressed as the probability of developing one additional case of cancer per population of one million. This value may be expressed as 1×10^{-6} or 1E-06.

The risks associated with non-carcinogenic chemicals are designated as non-cancer hazard and are represented as a ratio of site-related dose to a "safe dose" for a particular receptor and pathway. A ratio (termed hazard quotient, HQ) of 1.0 or less is considered to not pose a threat to human health. A ratio greater than one indicates that the possibility exists for adverse effects and that further evaluation or action is warranted. Exposure to multiple non-carcinogens within a single medium or multiple media is estimated by adding the individual HQs and is expressed as the cumulative hazard index (HI).

For non-carcinogens, USEPA and DEQ use a HQ or HI exceeding 1.0 as the departure point for whether additional evaluation or action is necessary (USEPA 1991, DEQ 2010b). For carcinogens, USEPA and DEQ use slightly different target levels for acceptable risk levels. In determining need for remedial action, differences exist in acceptable risk levels between CERCLA and State of Oregon guidance. USEPA's (1991) Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30, by Don Clay, entitled "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions," is quoted below.

> "Generally, where the baseline risk assessment indicates that a cumulative site risk to an individual using reasonable maximum (RME) exposure assumptions for either current or future land use exceeds the 10^{-4} lifetime excess cancer risk end of the risk range, action under CERCLA is generally warranted at the site. For sites where the cumulative site risk to an individual based on RME for both current and future land use is less than 10^{-4}, action

generally is not warranted, but may be warranted if a chemical specific standard that defines acceptable risk is violated or unless there are non-carcinogenic effects or an adverse environmental impact that warrants action. A risk manager may also decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where, for example, there are uncertainties in the risk assessment results. Records of Decision for remedial actions taken at sites posing risks within the 10^{-4} to 10^{-6} risk range must explain why remedial action is warranted."

In contrast to USEPA, DEQ uses an acceptable risk level of 1E-06 for individual carcinogens (including congeners of chemicals groups such as PCBs and carcinogenic PAHs [cPAHs]) and a level of 1E-05 for cumulative cancer risks (OAR 340-122-0115(2)(a) and (4)(a).

11.1.4 Data Management for HHRA

In Sections 5.0 and 6.0, the datasets evaluated in the Problem Formulation for the Upland and River OUs are described, including the methods used to handle data qualifiers and non-detect sample results. The approach used to calculate PCB totals from Aroclor and congener data, and toxicity equivalence quotients (TEQs) for dioxin-like PCB congeners, as well as the approach used to calculate PAH totals, are discussed in Appendix H. Finally, an evaluation of the data usability for the HHRA is provided in Section 7.4, whereby MDLs and MRLs for non-detect samples and MRLs for J-flagged data are compared to SLVs protective of human receptors to assess the quality of the data. A more detailed discussion of the implications of using MDLs for non-detect samples in exceedance of human health-based SLVs is presented in the uncertainty assessment (Appendix O).

11.2 Problem Formulation - Upland OU

The problem formulation for the Upland OU evaluated potential exposures by human receptors and selected COPCs for each of the four upland AOPCs as well as for all the AOPCs combined.

11.2.1 Exposure Setting and Potentially Exposed Populations

The current and likely future uses of land and water are the basis of identifying human receptors who may be exposed to site media. Beneficial uses of land and water have been discussed earlier in Section 3.0. As noted in Section 3.0, Bradford Island is part of the Bonneville Dam Complex. Land uses at the Island are governed by the Bonneville Master Plan (USACE 1997a) and include land uses for management of hydropower, navigation, recreation, and natural resource and wildlife preservation. Residential uses do not currently occur at the Island and are not included in the Master Plan, thus making future residential use very unlikely.

Shallow perched groundwater in the Upland OU is encountered at depths of approximately 7.5 ft bgs in the winter but may drop to depths of 30 ft bgs in the summer (Appendix D).

There are two enclosed structures in the general vicinity of the Upland OU AOPCs – the service building and the equipment building (the sandblast building was recently demolished). The service building and the equipment building are occupied structures located outside the boundaries of the Sandblast Area AOPC.

The three distinct human populations in the general site area are the site staff, site visitors, and the nearby residents. There are currently no on-site residents. Although a hypothetical future

resident is often considered in risk assessment, this scenario was not included in this HHRA because of the current and continuing industrial nature of the site and the requirements of the Master Plan.

Site Staff

As noted in Section 3.1.6.1.2, there are 162 full-time employees and approximately 475 part-time or seasonal contractors and researchers at the Bonneville Dam Complex. Among the full-time employees, 152 people may be engaged in a wide range of occupations, including maintenance, construction, office staff, visitor services, and natural resource management. An additional 10 additional staff from the Portland District headquarters are also stationed at the dam. Among the part-time personnel, approximately 300 fisheries-related staff (contractors/researchers from state and federal agencies) may work at the dam from April through September and an additional 175 construction and service contractors may also be employed at the project. Their number varies depending on workloads (McCavitt, personal communication, 2006).

The range of occupations may include soil-intrusive activities that may extend from the surface soils (e.g., mowing) to deeper soils (e.g., construction and utility services). They may also include indoor occupation of the service center building and equipment building (Figure 3-4), which are located adjacent to the Sandblast AOPC boundary but susceptible to vapor intrusion from VOCs in the soil and groundwater.

Construction workers engaged in long-term construction of new facilities (assumed exposure duration of 250 days for a year, per DEQ guidance) are not considered a reasonable scenario since major new construction is not planned for the Upland AOPC areas. However, the construction and service contractors may include excavation and trench workers engaged in utility repair or other types of soil-disturbing activities (assumed exposure duration of 9 days for a year, per DEQ 2010b) may be present. For the screening-level purposes of the problem formulation, both long-term construction workers and short-term excavation workers are included as potential receptors and are evaluated using DEQ's SLVs for each of these receptor types.

Site Visitors

Direct access by the general public or trespassers to the Upland OU areas is unlikely. Although a road from Interstate 84 provides access to the Bonneville Dam complex, the access road is gated, and visitors are only allowed to access several dam facilities (visitor centers, fish ladders, etc.). The site and general vicinity on Bradford Island is gated and off limits to the public. Only USACE personnel and authorized visitors are allowed into these areas.

Nearby Residents

As described earlier, no permanent residential dwellings are located on the Project. The primary population center in proximity to the dam is the town of North Bonneville, situated on the Columbia River just west of the dam on the Washington side of the river. The 2009 population is estimated at approximately 950 persons.

In summary, based on considerations of land use and site access, the human receptors who may be directly or indirectly exposed to COIs and COPCs at or from the upland AOPCs include:

- On-site adult outdoor workers
- On-site adult indoor workers

- On-site long-term construction workers and short-term excavation workers
- Potable Water Users - Hypothetical consumers (i.e., staff workers) of on-site groundwater
- Off-site child and adult recreationists and recreational and subsistence fishers and consumers of river water

The exposure scenarios and exposure routes associated with these receptors are described below.

11.2.1.1 Exposure Scenarios

The on-site receptors may be exposed to soils and groundwater at the Upland OU in several ways, as described below:

- Adult outdoor site maintenance worker engaged in activities that do not involve a significant degree of soil disturbance (e.g., landscape workers). These receptors at Bradford Island may be exposed to COIs in surface soil (0-3 ft bgs) by incidental ingestion, inhalation (dusts and vapors), or dermal contact with contaminants in soil.
- Adult indoor workers may be exposed to VOCs emanating from subsurface soil and entering the indoor environment by vapor intrusion if occupied enclosed structures were to be constructed in the future at the Sandblast Area.
- Construction workers and excavation workers may be exposed to COIs in surface and subsurface soil by incidental ingestion, inhalation (dusts and vapors), or dermal contact with contaminants from surface and subsurface soil combined (0-10 ft bgs) on an intermittent, short-term basis. They also may be exposed to COIs in shallow groundwater by incidental ingestion, dermal contact, and vapor inhalation during those times of the year when the perched groundwater is at shallow depths. The only exception would be at the Bulb Slope AOPC, which is too steep to support routine excavation activities. Long-term exposure such as those experienced by construction workers is unlikely since there are no plans to build extensive new structures or facilities in the Upland OU.
- Adult workers at Bradford Island hypothetically may be exposed to COIs in groundwater if it was used as a drinking water supply – although such use of groundwater does not currently exist and is not anticipated in the future. If such use were to occur, it is assumed for this evaluation that the groundwater would be used "as is", i.e., in an untreated and unfiltered condition.

Off-site receptors who may be indirectly exposed to chemicals from the Upland OU (and evaluated for the River OU, see Section 11.3) include:

- Child and adult recreationists who wade, swim, or boat in the Bonneville Forebay may be exposed by direct contact to COIs that may be discharged from groundwater to surface water.
- Child and adult subsistence and recreational fishermen may consume fish and shellfish contaminated with bioaccumulative COIs that erode from upland soils to offshore sediments or discharge from groundwater into the offshore surface water. Clams in the vicinity of the River OU are small and not of edible size. Sculpin are small fish that are an important component of the food-web but are not directly consumed by humans. Therefore, only crayfish and smallmouth bass are considered to be the most likely edible shellfish and resident finfish at the River OU. Although large-scale sucker are not popular

with subsistence or sport fishers, they may occasionally be consumed and are further evaluated in Appendix O. Subsistence fishers are likely to have higher fish ingestion rates than recreational fishers.

11.2.1.2 Exposure Areas

For the purpose of the problem formulation, exposure areas for the Upland OU and River OU (see Section 11.3) are defined on the basis of probable exposure by the identified receptors and the nature of the site data. It was assumed that an adult worker may be exposed solely to the exposure media at a single Upland AOPC (e.g., soil and groundwater at the Landfill) or could be exposed to multiple Upland AOPCs (all four AOPCs) during the course of their working life. Therefore, the exposure areas for the Upland OU include four individual AOPCs as well as a combined larger exposure area consisting of all four AOPCs combined.

Landfill AOPC

This area includes exposure to soil and groundwater at the Landfill.

Sandblast Area AOPC

This area includes exposure to soil, groundwater and soil gas at the Sandblast Area.

Pistol Range AOPC

This area includes exposure to soil and groundwater at the Pistol Range.

Bulb Slope AOPC

This area includes exposure to soil at the Bulb Slope.

All Four AOPCs Combined

This area includes exposure to soils from all four AOPCs, and to groundwater from the Landfill, Sandblast Area and Pistol Range AOPCs.

11.2.2 Conceptual Exposure Model

The CEM is a schematic representation of the source-receptor pathway at a site. The five elements that are required to be present in order to consider an exposure pathway complete or potentially complete are:

- A source of COIs (e.g., waste material in a landfill)
- A release mechanism (e.g., spills, releases)
- An exposure medium (e.g., surface soil)
- An exposure route (e.g., dermal contact with soil)
- A receptor (e.g., outdoor worker)

An exposure pathway is considered incomplete if any one of these elements is absent. Where there is no exposure, there is no risk, and no further evaluation of the pathway is warranted. A CEM should consider current and reasonably likely future land uses and exposures at a site.

A CEM was developed for each AOPC (Figures 11-1 through 11-4) on the basis of sources and site history, potentially exposed populations, the transport pathways and the routes of exposure. Exposure pathways are indicated as incomplete or potentially complete. The CEMs are generally similar for all the four AOPCs with some minor variations.

11.2.2.1 Landfill AOPC

The CEM for the Landfill AOPC is included as Figure 11-1. Releases from the waste materials disposed of at the Landfill have resulted in on-site exposure media that include surface soil, subsurface soil, and groundwater. The groundwater may also travel offsite, may daylight as seeps, and discharge to the surface water of the Columbia River.

The potential for erosion of landfill soils to occur is considered minimal or low, as discussed in Section 10.1.1. However, a portion of the soils along the north slope of the landfill are considered to be amenable to mass wasting (mass wasting soils) from potential slope failure. Further, evaluation of this pathway is addressed in this document and will be included in the upcoming FS. Because of the uncertainty associated with whether this pathway actually occurs and its magnitude, further discussion of this pathway is presented in the Uncertainty Assessment (Appendix O).

On-site receptors include outdoor workers who may be exposed to surface soils at the Landfill AOPC in their normal course of non-intrusive activities. Long-term construction workers and short-term excavation workers may be exposed to subsurface soils if they were to engage in soil-intrusive activities at the Landfill AOPC. Exposure routes related to soil include incidental ingestion, dermal contact, and outdoor inhalation of dusts and vapors. Those related to direct exposure to groundwater include dermal contact and inhalation of vapors within a trench setting for both construction and excavation workers. There are no enclosed structures present at the Landfill AOPC and none are planned. However, if enclosed structures were to be constructed in the future (assuming that constructability concerns are addressed), indirect exposures to groundwater would include volatilization of VOCs and subsequent vapor intrusion for indoor office workers.

In the unlikely event that new wells are installed, and untreated and unfiltered groundwater in the vicinity of the Landfill is used for potable uses, the on-site workers may be exposed to COIs in groundwater by ingestion, dermal contact, and inhalation of vapors. COIs in seep water and shoreline wells at the Landfill are unlikely to become part of the potable water supply for the Island but are included in the potable use evaluation as an intentionally conservative measure. These seep and groundwater COIs are more likely to become part of the transport pathway into the river.

COIs from soil washoff or groundwater discharge entering the river may subsequently be consumed by downstream users who use river water as their potable water supply source (assumed to be untreated and unfiltered). The bioaccumulative COIs may also enter the food web when taken up into the tissues of edible species such as the crayfish and smallmouth bass. Recreational and subsistence anglers (adults and children) may then consume these edible species. The anglers may also come in contact with COIs that may be discharged from groundwater into surface water, although this is likely to be an insignificant exposure. No direct contact exposures with sediment are considered likely for the mass wasting soils that may enter the Forebay since it is too deep for wading. Therefore, only bioaccumulation exposures are

considered potentially complete and significant exposure pathways associated with the transport pathway to the River OU.

11.2.2.2 Sandblast Area AOPC

The CEM for the Sandblast Area AOPC (Figure 11-2) is similar to that for the Landfill AOPC. Transport pathways, receptors and potentially complete exposure pathways for on-site and off-site soil and groundwater are the same as for the Landfill AOPC. No seep water or shoreline surface water data were collected for this AOPC. The available groundwater data include data collected from monitoring wells and from direct-push samples. A limited portion of Pistol Range soils along the shoreline may be considered to be "erodible soils." Discussion of the soil erosion pathway is provided in the Uncertainty Assessment (Appendix O).

In addition to these pathways, the Sandblast Area AOPC includes pathways related to VOCs. The release of VOCs associated with the historical AST and painting operations at this AOPC resulted in the presence of VOCs in soil gas and groundwater. Although there are no currently occupied buildings at this AOPC, the potential for intrusion of vapors from the subsurface (from soil gas and groundwater) into indoor environments exists, if enclosed structures were to be constructed here in the future. Therefore, exposure pathways for indoor inhalation of vapors by indoor workers may be potentially complete under future conditions.

11.2.2.3 Pistol Range AOPC

The CEM for the Pistol Range AOPC (Figure 11-3) illustrates the more limited set of receptors and potentially complete exposure pathways for this AOPC. Sources at the Pistol Range AOPC are related to its former use as a firing range. The exposure media are surface soil and groundwater. The groundwater is characterized by data for direct-push samples. Off-site transport pathways include the potential for surface soil to wash off into the adjacent lagoon and settle as sediment and for groundwater to discharge into the river. However, as described in Section 10.1.3, erosion of soils into the river is not likely to occur, due to the well-vegetated nature of the AOPC and the lack of soil-intrusive activities. Therefore, further discussion of this pathway is included in the Uncertainty Assessment (Appendix O) based on the assumption that erosion may have occurred in the past (historical erosion).

Adult outdoor workers may be exposed to surface soils by direct contact pathways. Although use of groundwater as a potable water source from this shoreline AOPC area is highly unlikely, grab sample data from the direct-push samples are used to evaluate this exposure pathway.

Off-site human receptors are also limited for this AOPC. Although wash-off from surface soils into the adjacent lagoon may occur, access is unlikely for human receptors to the lagoon and direct contact pathways are considered incomplete for lagoon sediment. Groundwater discharge to the river may lead to direct contact (potable use of surface water) and bioaccumulation (consumption of fish and shellfish) pathways that are complete for recreational and subsistence fishers.

11.2.2.4 Bulb Slope AOPC

The Bulb Slope AOPC is steep, rocky, and thickly vegetated with a thin layer of soil. The CEM for this AOPC (Figure 11-4) illustrates the fact that surface soil is the only medium of exposure.

Occasional exposure to surface soil may occur on the part of adult outdoor workers who may access this area for maintenance activities. Although very unlikely, the mass wasting soils may

also wash off into the Forebay with subsequent potential for bioaccumulation of COPCs into edible aquatic species (e.g., bass and crayfish) which may then be consumed by recreational and subsistence fishers and is discussed further in the Uncertainty Assessment (Appendix O). No other on-site or off-site exposure pathways or receptors are associated with this AOPC.

11.2.3 Methodology for Identification of Chemicals of Potential Concern

DEQ's risk assessment guidance allows a screening process to be applied to site data in order to separate chemicals that warrant evaluation from those that may be eliminated from further consideration (DEQ 2000, 2010b).

11.2.3.1 Identification of Contaminants of Interest

In Sections 5 and 6, the historical and recent site investigations are described in detail, and the COIs in Upland media of the four AOPCs are identified. Based on the presence of potentially complete exposure pathways and associated analytical data, COIs in the Upland OU were identified for the following media:

- Soil, groundwater, and co-located seep and surface water of the Landfill AOPC
- Soil and groundwater of the Sandblast Area AOPC
- Soil, groundwater, and lagoon sediment of the Pistol Range AOPC
- Soil of the Bulb Slope AOPC

The categories of COIs that were detected in analytical data include metals (including butyltins), pesticides, herbicides, PCBs, TPH, PAHs, other SVOCs, and VOCs. Of these COIs, a subset is considered to be bioaccumulative in soils, groundwater or aquatic environments (for the groundwater to surface discharge scenario), as presented in Section 7.3 and Table J-6. The screening process begins with the designation of all chemicals detected at the site as COIs, as described earlier in Section 9.1. The following essential nutrients were eliminated from the COI list due to their low potential for toxicity: calcium, magnesium, iron, sodium, and potassium in soil; calcium, magnesium, sodium and potassium in groundwater. The remaining COIs are then evaluated further on the basis of three criteria: detection frequency, comparison with reference concentrations (inorganics only) and comparison with risk-based screening levels. The first two steps of the COPC selection process were performed in Section 9.1 for all media associated with each AOPC (Tables 9-1 through 9-6).

The concentrations of the chemicals retained following the first two steps of the COPC selection process are then compared with risk-based screening levels. The chemicals that fail the HHRA screening process are designated as COPCs and are carried through the risk assessment process. The screening process and the development of the list of COPCs is a critical element of the Problem Formulation phase of the HHRA. The results of each step of the screening process are described in this section.

For groundwater, the COIs are reported as "dissolved" and "total." However, more emphasis is placed on the results of the total concentrations for the HHRA since the presumed exposure pathways for consumption of groundwater and surface water assume that unfiltered, untreated water is consumed as a potable water supply.

11.2.3.2 Detection Frequency

In the first step of the COPC identification process, for each medium of exposure at each AOPC, all COIs were evaluated with respect to their frequency of detection in a given medium. COIs that were detected at a frequency of 5% or less, given a sample size of 20 or more, were eliminated as COPCs. This criterion was not applied where the sample size was less than 20. The detection frequency criterion was applied to the media at each AOPC and also for the medium-specific data for all four AOPCs combined. Soil COIs were evaluated separately for the 0-3 ft and 0-10 ft depth intervals.

The use of the 5% detection frequency criterion is based on the assumption that site characterization is adequate and representative. COIs that were detected at less than 5% frequency are discussed qualitatively with regard to their nature and occurrence and implications for the HHRA in the Uncertainty Assessment (Appendix O).

The results of the evaluation of detection frequency are presented in Tables 9-1 to 9-6 and discussed in Section 9.1.

11.2.3.3 Statistical Comparison with Reference Area Soils

In the second step, the concentrations of inorganic COIs in soil at each AOPC were compared to concentrations in reference soils from the Island on the basis of statistical tests. The results of this statistical comparison are presented in Appendix L and discussed in Section 8.0. Inorganic COIs in soil at any of the AOPCs or the combined AOPCs were eliminated as COPCs if they were not statistically higher than reference concentrations (Section 9.1). This comparison recognizes that naturally occurring chemicals generally do not need to be addressed in a remedial context if there is no site-related contribution.

Concentrations of PAHs in soil at each AOPC were also compared to concentrations in reference soils on the basis of statistical tests. All PAHs in soils at each of the AOPCs exceeded PAH concentrations in the Reference Area soils (Table 8-1). Although this comparison was not used to select organic COPCs (in accordance with DEQ guidance), the results are presented to provide perspective on the distribution of organics between AOPC and reference soils.

11.2.3.4 Concentration-Risk Screen

The third step of COPC identification for the HHRA consists of comparing COI concentrations to risk-based screening concentrations that are specific to the media, receptors and pathways that are relevant to the site. DEQ guidance (DEQ 2010b) requires this step to consider exposure to: i) individual COIs, (ii) multiple COIs simultaneously within a given medium, and (iii) individual or multiple COIs within different media.

Carcinogenic and non-carcinogenic chemicals are evaluated slightly differently in the concentration-risk screen process.

11.2.3.4.1 Selection of Screening Level Values and EPCs

The risk-based SLVs for this HHRA represent concentrations of chemicals in each medium (soil, groundwater, soil gas) that are associated with acceptable target ELCR levels of 1 E-06 or a non-cancer HQ of 1.0. The selection of human health-based SLVs is described in Section 7.3 of the RI and generally included a hierarchical source structure with highest preference given to SLVs published by DEQ followed by USEPA. A few exceptions to the hierarchy were made, to accommodate DEQ preference or to take advantage of more up-to-date values, as described

below. For each medium, SLVs were selected for human health receptors, based on a hierarchy of sources (Appendix J, Tables J-4a through J-4f). The SLVs for each medium were selected to be protective of the human receptors that are likely to be exposed to that medium. Where multiple receptors and exposure pathways may exist for a single medium, the lowest of the relevant SLVs was selected.

SLVs for potable water use represent values that are protective of human health under the residential use scenario (i.e., ingestion of 2 liters/day as well as use of water for showering and household use) because of the designated beneficial uses for groundwater and surface water in this area and also because residential potable water use SLVs are available from both DEQ and USEPA to cover the range of COIs under evaluation. Therefore, use of the residential potable water SLVs is conservative since residential land use of groundwater will not occur at the Upland OU. Even if the groundwater were ever used as a potable water supply source on the Island, the assumed ingestion rate for the employees who may consume the water would be 0.7 liter per day (DEQ 2010b, USEPA 1997c) and would not include household use. Thus the residential potable water use SLVs may thus overestimate risk or hazard for the occupational consumption scenario by a factor of 3 due to the difference in water intake rates alone.

DEQ's vapor intrusion-based SLVs for groundwater were used to evaluate vapor inhalation in outdoor and trench settings for adult outdoor workers and construction and excavation workers. DEQ's soil gas SLVs were used to evaluate vapor inhalation in indoor settings for indoor office workers.

cPAHs were individually compared against their SLVs. For the benzofluoranthenes, historic data were reported as "total benzofluoranthenes" while recent data reported individual constituents such as benzo(b)fluoranthene and benzo(k)fluoranthene. The two types of data reporting were kept separate for SLV comparisons. In the absence of an SLV for total benzofluoranthenes, the lower of the SLVs for benzo(b)fluoranthene and benzo(k)fluoranthene was used for total benzofluoranthenes.

Each PCB Aroclor was compared to the Aroclor-specific SLV. In addition, the sum of the Aroclors, designated as Total PCBs, was compared to the SLV for PCBs. The source of the PCB SLVs were the RSLs from USEPA (USEPA 2010). The RSLs were identical for all the reported Aroclors in the Upland AOPC soils and were also used for Total PCBs.

For bioaccumulation-related pathways, bioaccumulation-based SLVs were identified or developed, as necessary. COIs were retained as COPCs for the bioaccumulation pathway under three conditions: (i) if they exceeded bioaccumulation-based SLVs for sediment, surface water or tissue; (ii) if they were considered bioaccumulative but lacked a bioaccumulation-based SLV; and (iii) if they were detected in tissue even if they were not considered bioaccumulative.

COIs without bioaccumulation-based SLVs were evaluated with regard to their bioaccumulation potential (Tables J-6 and J-7) to determine if they should be retained as COPCs. The bioaccumulation pathway applies to the Subsistence and Recreational Fishers and the exposure is highly dependent on chemical migration through multiple media. For example, the bioaccumulation exposure pathway may be direct for receptors consuming fish or shellfish and the COIs in the tissue, but SLVs for sediments and groundwater, derived based on the migration of the chemical between media to the surface water and ultimately in the fish tissue, should be considered highly variable and uncertain. .

11.2.3.4.2 Application of Screening Level Values

The SLVs were applied to the COPC selection process by comparing site concentration (C) to the SLV, where C is the lower of the 95% UCL or the maximum concentration, which is consistent with risk assessment guidance (USEPA 1989). For soil gas, only the maximum concentration was used.

Individual and Cumulative Screening

Exposure to Individual COIs (Carcinogens and Non-carcinogens) - COIs were retained as COPCs if the site concentration (lower of the 95% UCL or maximum concentration per USEPA 1989, DEQ 2010b) of an individual COI in soil and groundwater or the maximum concentration in soil gas exceeded the SLV, as illustrated in the C/SLV ratio below, where C is the concentration of the COI:

$$\frac{C}{SLV} > 1.0$$

Thus, in this first step, carcinogens with concentrations exceeding a screening risk level of 1E-06 and non-carcinogens exceeding a screening level of HQ of 1.0 in a single exposure medium were retained as COPCs. For some inorganics, the SLV in soil or sediment was based on the Reference UPL. For these chemicals, C/SLV does not indicate that an acceptable risk level was exceeded, only that the site concentration is greater than the Reference UPL. These were also retained as COPCs.

There were a few exceptions to this rule:

One exception was that, in any medium in which PCE or TCE was selected as a COPC, all the potential degradation products (dichloroethenes and vinyl chloride) were also retained as COPCs regardless of whether or not they were detected and whether or not they exceeded their own SLVs (if SLVs were available). This is meant to allow for the possibility that concentrations of these degradation products may increase in the future. This approach is recommended by DEQ (2010b).

The other exception was in the selection of COPCs for the pathway of groundwater discharge to surface water and subsequent bioaccumulation. Only those COIs in groundwater that had bioaccumulation-based SLVs or had bioaccumulation potential (even if no bioaccumulation-based SLVs were available) were evaluated for this pathway. When available, total analyte concentration data were used in preference to dissolved concentration data for the HHRA.

Exposure to Multiple COIs within a Single Medium (Non-carcinogens only) - Cumulative exposure to multiple COIs was performed for non-carcinogenic chemicals per DEQ's guidance. Recently published guidance from DEQ (2010b) does not require carcinogens to be included in this screening step since it is unlikely that more than 10 carcinogens would exceed their individual screening levels.

A non-carcinogenic COI was retained as a COPC if the individual ratio exceeded 0.1 when the sum of the C/SLV ratios for all the COIs in a given medium exceeded 1.0. This relationship is expressed as follows:

$$\frac{C}{SLV} > 0.1 \text{ when Sum } \frac{C}{SLV} > 1.0$$

Thus, in this second step, if the non-carcinogenic HI exceeds 1.0, contributing chemicals were identified as COPCs if they are present at one-tenth of their SLV.

The C/SLV ratio for lead was not included in the sum. Although it is classified as a probable human carcinogen, lead is evaluated on the basis of SLVs developed from the pharmacokinetic blood lead model (USEPA 2010). Lead was compared to its SLV and evaluated separately with regard to its adverse effects. Also for inorganics COIs whose SLVs were based on Reference UPLs and were therefore not risk-based, were not included in the sum C/SLV. Any inorganic that exceeded their Reference UPL was already included as a COPC in the first step.

Exposure to Single COIs from Multiple Media (Carcinogens and Non-carcinogens) - Cumulative exposure to a single COI that occurs in multiple media (e.g., soil, groundwater and soil gas) was addressed by retaining a COI as a COPC in all media when the cumulative multi-media ratio for a single chemical exceeds 1.0.

$$\text{Sum } \frac{C}{SLV} > 1.0$$

Based on the human health risk assessment guidance (DEQ 2010), the multi-media exposure evaluation was interpreted to identify new chemicals, from the list of COPCs based on single media exposure. This applies in cases where COIs with C/SLV ratios do not exceed 1 within a single medium, but exceeds the threshold when summed with C/SLV ratios from other relevant media for the receptor. Therefore, if a chemical has already been selected as a COPC, that chemical was not further evaluated for multi-media exposure (this interpretation of the guidance was confirmed during a phone conversation with DEQ [DEQ 2012a]).

Consistent with DEQ guidance (DEQ 2010b, 2012b), all COPCs within a single group with a similar mode of action were ultimately retained as COPCs even if individual members of the group passed the screening criteria. This applied to cPAHs and PCB congeners.

For the Upland AOPCs, the multiple media evaluation also included the multiple exposure pathways that could be reasonably assumed for a single receptor. These included outdoor workers who may be exposed simultaneously to soils by direct contact while also using groundwater as a potable water supply source, consuming food that may have been exposed to bioaccumulative chemicals in groundwater (after groundwater discharges to surface water) and inhaling VOCs from soil gas in an indoor setting (Sandblast Area only). Such a combination of multi-pathway and multi-media exposure is extremely unlikely and was, therefore. not postulated in the CEMs. It was included in the COPC selection process only to allow a high degree of confidence in the intentional conservatism of the screening process. Similarly, construction and excavation workers are assumed to be exposed to 0-10 ft bgs of soils, while also encountering groundwater in a trench setting with subsequent dermal contact and vapor inhalation.

Cumulative Risks and Hazards

At the conclusion of the Concentration-Risk screening, the sum of the C/SLV ratios for individual non-carcinogenic COIs (from Step 1) were summed to provide a screening-level estimate of the non-cancer Hazard Index (HI) for that medium. Lead was not included in the HI estimate but was evaluated and discussed separately. The C/SLV ratios for the carcinogens were also summed separately and multiplied by 1E-06 to provide an estimate of the ELCR. The purpose of these HI and ELCR estimates is to provide a screening-level estimate of non-cancer hazards and cancer risks.

Interpretation of the C/SLV ratios must be performed with caution and an understanding of the assumptions and limitations. For carcinogens, a single chemical C/SLV ratio of 1.0 corresponds to a screening level ELCR estimate of 1E-06 (one in one million). A ratio of 10 would represent a risk level of 1E-05. For non-carcinogens, a C/SLV ratio of 1.0 represents a HQ of 1.0 and any higher values represent corresponding increases in the HQ. Therefore, the cumulative non-carcinogenic C/SLV ratios listed at the bottom of the screening tables can be interpreted as a cumulative HI for the non-carcinogens.

The cumulative carcinogenic C/SLV ratios were multiplied by a factor of 1 E-06 to provide a screening-level estimate of cumulative ELCR. However, it is noted that the cumulative C/SLV ratios for carcinogens does not account for the non-carcinogenic effects associated with carcinogenic chemicals. If a quantitative estimation of risk were to be performed, the non-carcinogenic hazards associated with the carcinogenic COPCs would need to be included with the HQs for the non-carcinogens to arrive at an estimate of the HI. This uncertainty did not affect the COPC selection process since the lower of the cancer and non-cancer-based endpoints was the basis of the selected SLV. It also did not affect the findings and conclusions of the problem formulation since consideration of the cancer-based endpoints for carcinogenic COPCs generally leads to estimation of higher risk levels and the need for remedial responses at lower concentrations than consideration of the non-carcinogenic effects for the same chemicals. Therefore, decisions based on protection of the cancer effects are usually also protective of the non-cancer effects.

In addition, the SLV for arsenic in soil is based on the Reference Area UPL and is not a risk-based number since the concentration of naturally-occurring arsenic is higher than the risk-based SLV, as is typical of soils in the western United States. Therefore, the C/SLV ratio for arsenic only represents magnitude of exceedance above background. It cannot be multiplied by 1E-06 to provide a screening level estimate of risk as was done for other carcinogenic COPCs. Arsenic was retained as a COPC in soil if statistical testing (as described in Section 8) showed that the site concentration of arsenic was higher than the Reference Area concentration (as described in Section 8) and if the 95% UCL (or the maximum, whichever is lower) for arsenic in soil at the AOPC had a C/SLV ratio greater than 1.0.

COIs Without SLVs

For all media and exposure pathways, COIs without SLVs were generally retained as COPCs if they were reported at greater than 5% detection frequency, in accordance with DEQ and USEPA guidance. More detailed discussion of COIs without SLVs is found in Section 7.3 and Appendix O. An exception was inorganic COIs without SLVs were eliminated as COPCs if they did not exceed reference concentrations. For the groundwater to surface water discharge pathway, COIs detected in groundwater that did not meet bioaccumulation criteria (Table J-6 and J-7) and did not have SLVs were dropped. In some cases, DEQ SLVs were not available due to the calculated value exceeding either the solubility limit or the saturation point. In these cases the COIs were also eliminated as COPCs.

Identification of List of COPCs

At the end of multi-step process described above, COIs were identified as COPCs if they met the following two criteria:

- Detected at greater than 5% frequency

- Exceeded Reference Area concentrations (inorganics only)

Along with any one of the following criteria:

- Single-chemical C/SLV ratio greater than 1.0 (i.e., ELCR greater than 1E-06 for carcinogens and HQ greater than 1.0 non-carcinogens)
- Single-chemical C/SLV ratio greater than 0.1 and multi-chemical sum C/SLV greater than 1.0 (non-carcinogens only)
- Multimedia C/SLV ratio greater than 1.0 (carcinogens and non-carcinogens)
- No SLV available, or degradation product of PCE or TCE

11.2.3.5 Risk Interpretation

In this final phase of the screening level risk characterization process, the quantitative and qualitative components of the risk screening (i.e., toxicity ratios) and uncertainty assessment are evaluated to gain a better understanding of the actual potential for human health risk. Multiple lines of evidence are considered to provide qualitative information for the chemicals listed as COPCs and to support interpretation of the estimated health hazard and ELCR.

Confidence in the SLV was a key consideration to assess overall confidence in COPC selection. If primary sources did not provide SLVs, on a case-by-case basis, surrogate values were used and/or values from a more conservative receptor or exposure pathway. For screening based on surrogate SLVs, risk may be over-or under- estimated. If a SLV from a more conservative receptor or exposure pathway (i.e., an SLV for an Outdoor Worker for an Excavation Worker [who has less overall exposure] or using a tapwater water SLV for direct contact exposure), was used, which caused the COI to be selected as a COPC, it is most likely a highly conservative selection. In this scenario, development of a more representative SLV would be recommended for the baseline HHRA.

For each AOPC and receptor, the COPCs identified with toxicity ratios greater than 1 (and greater than 0.1 for noncancerous chemicals with HI greater than 1) and determined to be significant contributors to risk, are plotted in Figures 11-5 through 11-18, and discussed in the text below. Those COPCs where only a limited number of exceedances were noted or if their exceedances were minor, were not included on the spatial distribution maps.

11.2.4 Screening Risk Characterization

This section provides the results of the COPC selection process for each AOPC. The C/SLV ratios are also used to provide a preliminary discussion of the most significant chemicals for each receptor and pathway.

11.2.4.1 Landfill AOPC

COIs detected in Landfill AOPC soil included metals, SVOCs, pesticides, herbicides, and PCBs, PAHs, TPH, and VOCs. COIs detected in groundwater included metals, herbicides, PAHs, TPH, and VOCs; while seep COIs included metals, SVOCs TPH, and VOCs; and surface water COIs included metals and TPH. The applicable receptors for the Landfill AOPC are outdoor workers, construction and excavation workers, potable groundwater user, and recreational and subsistence fishers (from groundwater and erosional soil transport pathways). Indoor workers were not

considered for this AOPC because construction of enclosed structures above the Landfill is unlikely but are discussed qualitatively below.

11.2.4.1.1 On-site Adult Outdoor Worker

The on-site adult outdoor worker is assumed to be exposed to soils 0-3 ft bgs by direct contact pathways (incidental ingestion, dermal contact, outdoor inhalation of dusts and vapors). The COIs were evaluated with reference to individual and cumulative exceedances of screening levels for the adult outdoor worker (Table M-1).

All chemicals that remained as COPCs after comparison with SLVs and the concentration-risk screen are summarized in Table M-12.

Non-carcinogenic COPCs – The overall non-cancer HI for multi-chemical exposure was 0.29 (excluding lead) and therefore below the health hazard threshold of 1 (Table M-1). All the COPCs that were evaluated as non-carcinogens have C/SLV ratios that were less than 1.0. Only lead was selected as a COPC, based on multi-media exposure to soil and groundwater. Lead concentrations exceeded their SLV at only three locations within the 0-3 ft bgs interval (BIL18, BIL22 and BIL27, Figure 11-5) but the EPC for lead (511 mg/kg) is lower than the SLV (800 mg/kg) and serves as an example of a COPC that is limited to very localized exceedances of low magnitude and unlikely to pose a significant risk to this receptor.

Carcinogenic COPCs – The cumulative screening level ELCR is 6.3E-05 (Table M-1) and falls within USEPA's risk management range. Among the identified COPCs, those with the highest chemical C/SLV ratios were the cPAHs, primarily benzo(a)pyrene and a few others. ELCR related to the cPAHs is 6.1E-05 and thus accounts for the majority of the cumulative ELCR. Total benzo(b)fluoranthenes were not included in the PAH count since the individual benzo(b)fluoranthenes were retained as COPCs. (Total benzofluoranthenes were reported in earlier data sets and have since been supplemented with more recent data reporting individual fluoranthenes). Total benzofluoranthenes, evaluated separately, had a C/SLV ratio of 11.6 (ELCR= 1.1E-05) and fell within the range of ELCRs for the other cPAHs.

Arsenic was the only other carcinogenic COPC with a C/SLV ratio greater than 1, but, was low at 1.94. The SLV for arsenic (5.4 mg/kg) was based on the reference concentration and does not represent a risk-based SLV (i.e., excluded from in the ELCR sum). The SLV exceedance occurs at four locations, but the risk ratio is primarily due to a single location (BIL05) where arsenic occurs at a concentration of 30.1 mg/kg. At all other locations, arsenic was generally reported at concentrations similar to reference concentrations.

All the detected Aroclors and total PCBs had single-medium and multi-media C/SLV ratios less than 1.0 and were, therefore, not retained as COPCs. As noted earlier, the potential non-cancer effects associated with carcinogenic COPCs are not evaluated in this COPC selection process but are unlikely to affect COPC selection.

COPCs without SLVs – SLVs were available for all the COIs listed. Therefore, no COPCs were identified on the basis of a lack of SLVs.

Summary

There were eight COIs screened in as COPCs, which consist of metals and PAHs (Table 11-1). The COPCs contributing the most to health risk for the Adult Outdoor Worker at the Landfill AOPC include arsenic and cPAHs. Typically, two different patterns of spatial distribution were seen when a COI was identified as a COPC. The exceedances may either be due to substantially

elevated concentrations at a few locations (i.e., a few locations) or moderately elevated concentrations at many locations (dispersed). In some cases, the ratios exceeded 10 (i.e., screening risk level greater than 1E-05 or HQ greater than 10). The sample locations at the Landfill where SLVs were exceeded are shown in Figure 11-5. Among these, the locations where the C/SLV ratio exceeded 10 were primarily in the north-west corner of the Landfill AOPC. They included locations within the Gully Test Pit and nearby locations and in the Mercury Vapor Lamp Test Pit. The majority of the C/SLV ratios greater than 10 were for the cPAHs (in the Gully Test Pit). The modest exceedances of arsenic above its Reference Area UPL were dispersed throughout the Landfill AOPC and therefore are not indicative of any particular source area for arsenic.

11.2.4.1.2 Onsite Construction Worker

The construction worker is assumed to be exposed to a depth of 0-10 ft bgs soils for a period of 250 days for one year. Although some aspects of the construction worker's activities may have higher exposures than outdoor workers (e.g., incidental soil ingestion rate of 330 mg/day versus 100 mg/day for the outdoor worker), their overall exposure dose is lower than the outdoor worker because of the much shorter duration of exposure (one year versus 25 years). Therefore, the SLVs developed for construction workers are generally higher (i.e., less stringent) than the SLVs for outdoor workers (except for certain non-carcinogenic chemicals which are not affected by the exposure duration difference). For COI's lacking construction worker-specific risk based concentrations (RBCs) , the outdoor occupational worker RSLs were used and represents the use of SLVs that are probably more conservative than needed (from DEQ 2009b). For the deeper soil interval, the COPC list was almost identical to that of the shallow soil depth interval but contains fewer chemicals (Table M-2). The complete list of COPCs is summarized in Table M-12.

Non-carcinogenic COPCs – No non-carcinogenic COPCs exceeded a C/SLV ratio of 1, and the overall non-cancer HI for multi-chemical exposure was 0.90 (excluding lead) and therefore below the health hazard threshold of 1. The UCL for lead (796 mg/kg) was slightly lower than its SLV of 800 mg/kg (Table M-2).

*Carcinogenic COPCs –*The cumulative screening level ELCR is 1.2E-05 and falls within USEPA's risk management range. This evaluation was conservative since the more stringent adult outdoor worker SLVs (based on USEPA industrial soil RSLs) were used for many COIs for which construction worker SLVs were not available.

The COPCs with the largest C/SLV ratios and major contributors to ELCR for this receptor were PCE and benzo(a)pyrene. The ELCR due to cPAH COPCs was estimated at 5.1E-06 (Table M-2). Individual Aroclors and total PCBs did not exceed a ratio of 1.0 either on a single-medium or a multi-media basis and were eliminated as COPCs.

COPCs without SLVs - SLVs were available for all the COIs listed. Therefore, no COPCs were selected solely due to a lack of SLVs.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes, TCE, and vinyl chloride) were also included in the list of COPCs for future consideration, but it should be noted that none of these degradation products were detected.

Summary

There were seven COIs screened in as COPCs, which consist of PAHs, SVOCs, and VOCs. The COPCs contributing the most to health risk the Construction Worker at the Landfill AOPC include benzo(a)pyrene and PCE (Table 11-1) . The locations with SLV exceedances for the construction worker risk contributing COPCs are shown in Figure 11-6. The locations with cPAHs exceeding a risk level of 1E-05 were limited to the Gully Test Pit, a few nearby locations and the Mercury Vapor Lamp Test Pit. Elevated PCE was only found at one location in the Gully Test Pit.

Onsite Excavation Worker

DEQ's RBCs (2003, updated 2009) assume that an excavation worker may be exposed to contamination for nine days during one year of exposure. Therefore, a screening evaluation for the excavation worker was also performed (Table M-3). SLVs that are specific to the excavation worker are even lower than for the construction worker due to the fewer number of days exposed in a year.

The overall non-cancer HI for multi-chemical exposure was 0.73 and therefore, less than the threshold value of 1. The cumulative ELCR was 8.0E-07, which is below the threshold risk level of 1E-06. No COPCs were identified and therefore, there are no unacceptable risks to the Excavation Worker due to exposure to soils.

11.2.4.1.3 Groundwater Exposure – Construction/Excavation Worker

During the winter, there is a possibility that construction and excavation workers may encounter shallow perched groundwater during the course of soil-intrusive activities. Preliminary COPC concentrations in groundwater were compared to DEQ's SLVs for this receptor and pathway (Table M-4).

Some metals and DNOP screened in as COPCs, but this was due to using the tapwater SLVs because DEQ did not list direct contact SLVs for these chemicals. Although the much more conservative tapwater SLVs were used, the C/SLV ratios were still very low with iron being the highest at 1.1. Upon closer evaluation, antimony, mercury, and DNOP lacked DEQ RBCs due to their calculated SLVs exceeding their respective solubility limits for this pathway. It should be noted that for metals, the listed direct contact to groundwater RBCs were four to six orders of magnitude greater than their respective tapwater RBCs. Given these reasons, the screened in COPCs should be dismissed. Therefore, there are no unacceptable risks to the Construction Worker and Excavation Worker due to direct contact exposure to groundwater.

11.2.4.1.4 Groundwater User for Potable Use

Groundwater data collected from monitoring wells over the period 1998 to 2009 were compared to the SLVs for potable water use. The targeted Landfill AOPC receptor, assumed to utilize the groundwater for potable use, is the Adult Outdoor Worker though this screen could conservatively apply to any hypothetical onsite worker who may be a potable water user. As listed in Table M-5, the COPCs identified included a number of metals, several VOCs, SVOCs, and TPH fractions. The chemical with the highest C/SLV ratio was arsenic, followed to a lesser degree, by PCE, vinyl chloride and DRO. The full list of COPCs is summarized in Table M-12.

Non-carcinogenic COPCs – The non-carcinogenic COPCs exceeded a C/SLV ratio of 1, and the overall non-cancer HI for multi-chemical exposure was 11. The primary contributor to this HI was DRO (C/SLV=4.3), followed, to a lesser degree, by manganese (C/SLV=2.2), DNOP

(C/SLV=1.1) iron (1.1) and RRO (C/SLV=1.2). None of these ratios were considered significant given the conservatism inherent in using residential potable water SLVs for this AOPC. If it were assumed that the occupational potable use of groundwater is one third that of the residential water use, then DRO would be the only one of these analytes that would exceed a C/SLV ratio of 1.0.

The remaining COPCs exceeded the potable use SLVs by relatively small margins or were included only because of multi-chemical (i.e., C/SLV greater than 0.1 when sum C/SLV exceeds 1.0) and multi-media exposures (antimony, lead, zinc, GRO, 1,2,4-trimethylbenzene). These analytes do not exceed their individual SLVs at any location. Further, even the multi-media C/SLV ratios for antimony, zinc and GRO were less than 1.0 and, therefore, health concerns related to these analytes are unlikely. Iron and zinc are essential trace elements for human nutrition and is typically not considered to be toxic at such low concentrations.

Carcinogenic COPCs – The cumulative ELCR was 3.2E-04, primarily due to arsenic. Arsenic had a C/SLV ratio of 274 (ELCR of 2.7E-04), due to its extremely low SLV of 0.000038 mg/L. It should be noted that total arsenic concentrations in the upgradient Reference Well were reported in the range of 0.00122 to 0.00168 mg/L (Table I-6) and were also above the SLV for potable water. The maximum reported concentration in Landfill AOPC groundwater (maximum reported concentration of 0.0213 mg/L (Table I-1) and a 95% UCL value of 0.010 mg/L) was about 10 times higher than the upgradient concentration. Thus, the upgradient arsenic concentrations were approximately 35 times higher than the SLV and Landfill AOPC groundwater was about 270 times higher than the SLV. Arsenic exceeded its SLV by more than a factor of 100 at several locations (Figure 11-7). The potable water SLV for arsenic is a strictly risk-based value that is routinely exceeded in groundwater just as naturally occurring arsenic in soil routinely exceeds the risk-based soil SLV. Therefore, it is common and useful to also compare arsenic to the maximum contaminant levels (MCL) of 10 µg/L (Appendix J, Human Health SLVs; DEQ 2010a) when considering potable water uses. By this standard, the 95% UCL for arsenic in landfill groundwater (10.4 µg/L, Table M-5) is essentially equal to the MCL. Therefore the ELCR of 2.7E-04 for arsenic is considered to be an artifact of the screening process and does not necessarily mean that the groundwater is unsuitable for potable use.

Other carcinogens with C/SLV ratios greater than 1 included PCE, vinyl chloride, chloroform, and B2EHP. Among these, PCE and vinyl chloride exceedances are significant because of their high potential for toxicity and they were detected in approximately 25% of the samples and their UCLs were associated with risk levels corresponding to 3E-05 and 1.2 E-05, respectively (Table M-12).

It should also be noted that potable water use SLVs for VOCs such as PCE, its degradation compounds and chloroform are influenced most by the inhalation route, i.e., inhalation of the VOCs during household uses such as showering (USEPA 2010). In the case of the Upland AOPCs, hypothetical potable use of groundwater would primarily consist of ingestion and minimal exposure by the inhalation route.

COPCs without SLVs - SLVs were available for all the detected preliminary COPCs. Therefore, no COPCs were selected solely due to a lack of SLVs.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes and TCE) were also included in the list of COPCs for future consideration, but

it should be noted that these degradation products were detected minimally (less than 5% detection frequency) and in most cases not detected at all.

Summary

There were 19 COIs screened in as COPCs for potable use of groundwater, which consist of metals, TPH, SVOCs, and VOCs (Table 11-1). The COPCs contributing the most to health risk for the potable water user exposed to Landfill AOPC groundwater include arsenic, manganese, chloroform, PCE, vinyl chloride and DRO. Locations with metal SLV exceedances are shown on Figure 11-7. Exceedances for several COPCs occurred at all the monitoring wells within the Landfill AOPC. Arsenic exceeded 1E-05 risk levels at all the wells. Locations with organic SLV exceedances are shown on Figure 11-8. Exceedances of PCE above 1E-05 were noted along the northern side of the Landfill AOPC.

11.2.4.1.5 Groundwater Discharge to Surface Water

A description of the migration pathway for groundwater is included in Section 10.1.1 and concludes that the pathway exists for discharge to surface water, but that the water is subject to rapid dilution as soon as it reaches the river.

To evaluate the transport pathway from a human health standpoint, the recently collected groundwater data from the Landfill AOPC were compared to data collected from the seep locations and the adjacent surface water locations (Table M-6). COIs that were detected in groundwater, seeps, and shoreline surface water were considered to be representative of how COIs act within this transport pathway. The C/SLV ratios were calculated for the maximum concentrations reported in groundwater, seep water, and shoreline surface water. For the majority of the COIs, substantial reductions in concentrations and C/SLV ratios occurred along the flow path from groundwater to seep water to shoreline surface water locations. The exceptions were iron and lead which showed little reduction or a slight increase. The only COPC with a C/SLV ratio exceeding 1.0 at the shoreline surface water was arsenic. However the maximum arsenic concentration in the surface water (0.00117 mg/L) was similar to the maximum groundwater concentration observed at the Reference Area well (0.00168 mg/L) (Table M-6). This trend appears to hold for the other metals as well where the shoreline surface water concentrations are similar to reference area groundwater concentrations.

There is evidence of a transport pathway where COPCs may move between the groundwater to seep water to surface water, but the potential for discharge of COPCs in Landfill groundwater into the river surface at levels of concern appears to be low. The human health impacts of the media within this transport pathway are potable use and bioaccumulation into fish and selfish. This is discussed in further detail below.

Groundwater Discharge and Bioaccumulation

Groundwater for potable use is discussed in Section 11.2.4.1.4. Those COIs that exceeded bioaccumulation SLVs in groundwater were retained as COPCs for the bioaccumulation pathway (Table M-7) for the Subsistence Fisher and Recreational Fisher receptors. The bioaccumulation pathway is a potentially complete exposure pathway for all the receptors evaluated for the Landfill AOPC. Onsite workers may opt to fish recreationally on their time off. For the multi-media screening, the Adult Outdoor Worker was chosen to represent onsite receptors. The COPCs retained for this pathway are listed in Table M-12

Non-carcinogenic COPCs –The HI of 5.8 exceeds the health hazard threshold of 1.0 and is primarily due to DNOP. Although the C/SLV ratios for iron and manganese were greater than 1.0, the SLVs were based on aesthetic effects related to water consumption (Oregon Water Quality Criteria [WQC], Table 33b) and are not indicative of human health effects. Since these analytes are not considered to be bioaccumulative, their C/SLV ratios are not included in the HI. Some additional metals were also selected as COPCs due to their cumulative contribution to the non-cancer hazard. Their individual C/SLV ratios were less than 1.0 except thallium which had an C/SLV ratio of 1.0. It should be noted that DNOP was not selected as a COPC for tissue in the River OU.

Carcinogenic COPCs – The cumulative ELCR was 6.0E-04, which exceeds the risk management range and was primarily due to arsenic. Arsenic concentrations exceeded the SLVs by more than a factor of 10 at all monitoring well locations including seep and shoreline surface water locations (Figure 11-9). PCE and vinyl chloride also had C/SLV ratios greater than 1, but should be noted that these volatile compounds do not meet the criteria used to identify bioaccumulation potential (Table J-7). B2EHP concentrations exceeded the SLV at three locations: MW-1, MW-2 and MW-4 in the interior but not in any of the more exterior monitoring well locations and seep water samples (Figure 11-9; Table M-8); therefore the potential for discharge to the river at levels of concern appeared to be low.

COPCs without SLVs –Lead, mercury, tributyltin, and three VOCs (1,2,4-trimethylbenzene, isopropylbenzene, and n-propylbenzene) were screened in as COPCs because bioaccumulation-based SLVs are unavailable and they may have some potential for bioaccumulation based on their BCF or octanol-water coefficients (Table J-6). Mercury was detected at extremely low concentrations with a UCL of 0.000077 mg/L (Table M-7) and had a low detection rate (17%) in four of 24 samples. Also, detections were only in wells from the interior of the Landfill but not in any of the exterior wells (MW-01, MW-03, MW-08, MW-09, Appendix A). It also did not exceed the residential potable user SLV. Therefore, the potential for discharge of mercury into the river at concentrations of concern for human health appears to be low. VOCs are unlikely to persist in the aquatic environment after discharge to surface water and would typically not be expected to bioaccumulate in tissue. Although there is no bioaccumulation-based SLV for tributyltin, the residential potable water SLV for tributyltin is available (11 µg/L) and was not exceeded at any location.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes and TCE) were also included in the list of COPCs for future consideration, but it should be noted that these degradation products were detected minimally (less than 5% detection frequency) and in most cases not detected at all. Again, VOCs are unlikely to persist in the aquatic environment and typically do not bioaccumulate in tissue.

Summary

There were 18 COIs screened in as COPCs, which consist of metals, SVOCs, and VOCs (Table 11-1). The COPCs contributing the most to health risk for the Landfill AOPC groundwater for the bioaccumulation pathway include arsenic, DNOP, PCE, and vinyl chloride.

Seep Water

The seep water samples represent a limited data set that was collected primarily to evaluate the groundwater transport pathway. Use of seep water and shoreline surface water for potable water

use is neither practical nor feasible due to their location. Similarly, the most robust evaluation of bioaccumulation potential is performed on the basis of River OU surface water and tissue data (see Section 11.3.4). No statistical analysis of these data was performed and the detected COIs were compared to SLVs and no inferences regarding HI or ELCR were made. Tables M-8 and M-9 list the COPCs for the two seep water sample locations that were identified for potable water use, and for discharge to surface water and subsequent bioaccumulation pathways, respectively.

COPCs identified for potable water use included metals, several VOCs, and TPH (Table M-8). Non-carcinogenic COPCs included antimony, iron, lead, manganese and DRO. Carcinogenic COPCs were arsenic, chloroform, and PCE. Degradation products of PCE were also included. Among the COPCs listed, arsenic is already retained as a COPC for the groundwater discharge pathway (Table M-6). Chloroform and PCE (and its degradation products) are unlikely to persist in the River OU since they are VOCs.

COPCs identified for the discharge and bioaccumulation pathway included arsenic, lead, mercury, and PCE (and its degradation products) (Table M-9).

Shoreline Surface Water

Tables M-10 and M-11 list the COPCs that were identified for potable use, and for discharge to surface water and subsequent bioaccumulation pathways, respectively, for the shoreline surface water samples. Arsenic was the only COPC identified for potable use and was already included as a COPC for groundwater (Table M-12). Arsenic and lead were screened in as COPCs for bioaccumulation.

11.2.4.1.6 11.2.4.1.6 Volatilization of VOCs from Groundwater

VOCs in groundwater at the landfill may volatilize to the outdoor air. In the extremely unlikely event that enclosed structures are built at the landfill, intrusion of VOCs into the indoor environment may also occur. VOC concentrations in the groundwater were compared to DEQ's RBCs for outdoor inhalation of vapors and indoor inhalation of vapors in an occupational setting. All VOC concentrations were lower than their respective SLVs by more than two orders of magnitude. These comparisons are not presented in tables due to the infeasibility of construction at the landfill and the low likelihood of this pathway ever being complete.

11.2.4.2 Sandblast Area AOPC

COIs detected in Sandblast Area soil included metals, butyltins, SVOCs, pesticides, PCBs, PAHs, TPH, and VOCs. VOCs were also detected in soil gas. COIs detected in Sandblast groundwater included metals, butyltins, PAHs, TPH, and VOCs. Although PCE, TCE and dichloroethenes were detected in all media, vinyl chloride was detected only in groundwater. The applicable receptors for the Sandblast Area AOPC are outdoor workers, construction/excavation workers, potable groundwater user, indoor workers and recreational and subsistence fishers (from groundwater and erosional soil transport pathways).

COPC selection for the Sandblast Area AOPC included evaluation of data for soil, groundwater and soil gas, as described below. An additional set of data collected for surface soils at this AOPC included analysis of lead in two different soil particle soil fractions of less than 2 millimeter (mm) and less than 250 micrometers (μm). The goal of collecting these data was for

subsequent site-specific evaluation of the lead ingestion pathway for adult workers, should lead be selected as a COPC for soil.

11.2.4.2.1 On-site Outdoor Worker

The COPCs associated with the upper 3 feet of soils for this receptor are listed in Table M-13. The COPCs in surface soils include three metals (chromium, lead and arsenic), a few VOCs (PCE and TCE), and a few PAH compounds. The potential degradation products of PCE were also retained (Table M-13). In addition, as requested by DEQ for this AOPC only, lead was also evaluated and is retained as a COPC for the 0-1 ft bgs depth interval (Table M-13).

Non-carcinogenic COPCs - The cumulative C/SLV ratio resulted in an HI of 0.087, well below the health hazard threshold of 1, excluding the C/SLV ratios for lead. No single non-carcinogenic chemical other than lead had a single-medium C/SLV ratio greater than 1.0.

Lead was reported and evaluated in a more detailed manner than other analytes for this AOPC because of its known source and its potential toxicity. Its evaluation is consistent with USEPA recommendations for lead (USEPA 2000). Its occurrence as part of sandblast grit means that it may occur at higher concentrations in association with finer-grained soil particles and thus, may be more available for intake as part of inhalation and incidental ingestion pathways with subsequent release into the bloodstream. In addition, the particle-size relationship may also allow higher concentrations of lead in grit to be present in the surface soils from which most of the occupational exposure may occur. Therefore, lead samples were collected and analyzed to represent 2 surface depth intervals and three size fractions at this AOPC. The two surficial depth intervals were 0-3 ft bgs and 0-1 ft bgs. The size fractions included unsieved fractions, particle size fraction less than 2 millimeter (mm) and particle size fraction less than 250 micrometers (μm). The unsieved fraction provides total lead concentrations similar to all other analytes for soil samples. The 2 mm fraction represents total soil lead (without included chunks or larger particles that would typically not enter the ingestion and inhalation pathways). The less than 250 μm fraction represents the lead fraction most likely to be deposited on hands and other exposed body parts during direct contact followed by incidental ingestion.

The lead results shown in Table M-13 indicate that higher lead concentrations were reported in the 0-1 ft bgs interval and UCLs decreased when the 0-3 ft bgs interval was considered. In the 0-3 ft bgs interval, lead UCLs did not exceed the SLV of 800 mg/kg for any of the size fractions. In the 0-1 ft bgs interval, the lead UCL was close to the SLV for the 2 mm and the 250 um fraction (C/SLV ratios of 0.96 and 1.15, respectively). The unsieved total lead UCL was higher than the SLV and resulted in a C/SLV ratio of 4.08.

Because the C/SLV ratio for the most bioavailable lead fraction exceeded 1.0, lead is recommended for additional and more rigorous evaluation for this AOPC (Table M-20).

Carcinogenic COPCs – The cumulative ELCR was 2.2E-05, which falls within the risk management range. The COPCs with the greatest contribution to cumulative ELCR (i.e., highest single chemical C/SLV ratios) were PCE, and three cPAHs (benzo(a)pyrene, benzofluoranthenes, and dibenz(a,h)anthracene). cPAH COPCs were associated with an ELCR of 9.7-06 (Table M-13). Chromium was also included as a COPC based on the use of the SLV for hexavalent chromium. In the absence of site-specific chromium speciation data, it was conservatively assumed that all the detected chromium was the more toxic hexavalent chromium rather than the more common and much less toxic trivalent chromium. Arsenic was included as a

carcinogenic COPC but had a relatively low C/SLV of 1.8. The ratio exceeded 1.0 primarily because of a single location where it was reported at 80.9 mg/kg.

The distribution of the SLV exceedances is shown in Figure 11-9. The seven locations where total lead exceeded the SLV of 800 mg/kg (concentrations range from 921 mg/kg to 3,260 mg/kg) are primarily along the northern portion of the AOPC. Concentrations of VOCs exceeded their SLVs by more than a factor of 10 at only two locations near the current HMSA. Therefore, the areas of concern for VOCs are quite limited. Locations where PAHs exceeded their SLVs were more widespread and included the eastern edge and northwestern corner of the AOPC and two other isolated locations (HA3 to the north and DSA11 to the south). Arsenic had low level exceedances (C/SLV less than 10) at numerous locations throughout the AOPC. In addition, one station (SBB18) had a concentration (80.9 mg/kg) significantly higher than the SLV (5.4 mg/kg). Arsenic, chromium, PCE and TCE were retained as carcinogenic COPCs that are recommended for further and more rigorous evaluation.

COPCs without SLVs - SLVs were available for all the preliminary COPCs. Therefore, no COPCs were selected solely due to a lack of SLVs.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes, TCE, and vinyl chloride) were also included in the list of COPCs for future consideration, but it should be noted that these degradation products were detected minimally (less than 5% detection frequency) and in most cases not detected at all.

Summary

There were 11 COIs screened in as COPCs, which consist of metals, PAHs, and VOCs (Table 11-2). The COPCs contributing the most to health risk at Sandblast AOPC soil for the adult outdoor worker include lead, arsenic, chromium, benzo(a)pyrene, total benzofluoranthenes, and PCE. The locations with SLV exceedances are illustrated in Figure 11-10 and are seen to be fairly widespread in distribution.

11.2.4.2.2 On-site Construction Worker and Excavation Worker

Construction Worker

COPCs for the deeper soil depth interval are similar to the shallow soils, but fewer in number as shown in Table M-14.

Non-carcinogenic COPCs - The cumulative C/SLV ratio resulted in an HI of 0.11, which is well below the health hazard threshold of 1. No single chemical had a C/SLV ratio that exceeded 1.0 either on a single-medium or multi-media basis. Lead in the 0-1 ft bgs interval was not separately evaluated for this receptor (as it was for the Adult Outdoor Worker) due to the intrusive nature of their expected activities. Lead in the 0-10 ft bgs interval had a C/SLV ratio of less than 1.0 and was not identified as a COPC.

Carcinogenic COPCs - PCE and benzo(a)pyrene had single chemical C/SLV ratios greater than 1.0 and contribute the most to the cumulative ELCR of 7E-06, which is within the risk management range. The C/SLV ratio for PCE was on the order 2E-06. The risk levels associated with PAHs were slightly higher, up to a high of approximately 1.9E-06. All other COPCs had ratios less than 1.0 (Table M-14).

COPCs without SLVs - SLVs were available for all the COIs. Therefore, no COPCs were selected solely due to a lack of SLVs.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes, TCE, and vinyl chloride) were also included in the list of COPCs for future consideration, but it should be noted that these degradation products were detected minimally (less than 5% detection frequency) and in most cases not detected at all.

Summary

There were seven COIs screened in as COPCs, which consist of benzo(a)pyrene, PCE, and PCE degradation products (Table 11-2). The locations where C/SLV ratios exceeded 1.0 for PCE and benzo(a)pyrene are shown in Figure 11-11. The locations with exceedances of COPCs at levels greater than a factor of 10 are similar to those noted for the outdoor worker and are related primarily to the cPAHs.

Excavation Worker

The cumulative C/SLV ratio resulted in an HI well below the threshold of 1.0 and the cumulative ELCR was 8.1E-07, which is below the risk threshold. Likewise, there were no COPCs selected for the excavation worker (Table M-20).

Construction/Excavation Worker Exposure to Groundwater

As noted earlier, there is a possibility that construction and excavation workers may encounter shallow perched groundwater during the course of soil-intrusive activities. Preliminary COPC concentrations in groundwater were compared to DEQ's SLVs for this receptor and pathway (Table M-17).

The HI of 1.0 was primarily due to the only COPC, vanadium, which had an C/SLV ratio of 0.98. A DEQ SLV for direct contact to groundwater in a trench was not available for vanadium and, therefore, the tapwater SLV was used, which is considerably more conservative. As noted earlier, the groundwater direct contact RBC for metals are typically four to six orders of magnitude more than the tapwater RBCs and therefore vanadium should be dismissed. No non-carcinogenic or carcinogenic compounds had C/SLV ratios greater than 1.0. The cumulative ELCR was 3.6E-07 and below the threshold of 1E-06.

11.2.4.2.3 Indoor Office Worker

The maximum detected concentration of COIs in soil gas were used to identify COPCs in soil gas (Table M-16).

Non-carcinogenic COPCs - No non-carcinogenic VOCs were identified as COPCs since the cumulative C/SLV ratio was less than 1.0. No single chemical had a C/SLV ratio that exceeded 1.0 either on a single-medium or multi-media basis.

Carcinogenic COPCs - PCE and TCE were the only primary COPCs with a cumulative ELCR of 2.1E-05. PCE and TCE were the only COPCs with single chemical ratios greater than 1.0. The ratios for these chemicals were approximately 16 and 4, respectively, and correspond to risk levels of approximately 2E-05 and 4E-06. These fall within USEPA's risk management range but exceed DEQ's target risk levels for individual COPCs.

COPCs without SLVs - Soil gas SLVs were available for all detected COPCs with the exception of ethanol. Ethanol was reported in two of five samples with a maximum concentration of 13 $\mu g/m^3$ (Table I-13). Although it is volatile, ethanol is not considered to be a toxic VOC (USEPA 2002c). Therefore, ethanol was not retained as a COPC.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes, TCE, and vinyl chloride) were also included in the list of COPCs for future consideration. cis- and trans-1,2-DCE were detected well below their soil gas SLV. Vinyl chloride and 1,1-dichloroethene were not detected in soil gas. The degradation products for the soil gas medium is pertinent because once they are released into soil gas, the exposure potential for human receptors through the inhalation pathway is higher than if they were in soil or groundwater media.

Summary

There were six volatile COIs screened in as COPCs (M-20). The COPCs contributing the most to health risk at the Sandblast AOPC soil gas for the vapor intrusion pathway for the indoor worker include PCE and TCE. The locations with exceedances of the SLVs are shown in Figure 11-12. SB-12 had a C/SLV ratio of greater than 10 for PCE. SB-10 had a ratio less than 10. Although the locations of PCE and TCE exceedance in soil gas are not co-located with the exceedances for soil (see Figure 11-10), as discussed in Section 9.3.3, they are located within the footprint of the PCE groundwater plume and downgradient from the inferred PCE source area (storage tank historically stored at the location of the current HMSA). The exceedances of the soil gas SLVs are quite localized and limited to just 2 of the 5 sample locations neither of which is close to any occupied structures. The two locations with the exceedances are near the HMSA and the former sandblast building.

11.2.4.2.4 Groundwater - Potable Water User

COPCs in groundwater data from the monitoring wells were identified for the potable use exposure pathway and include metals, PAHs, VOCs and TPH (Table M-18).

Non-carcinogenic COPCs - Vanadium, several VOCs, DRO and GRO were identified as COPCs as contributors to the cumulative HI of 3.2, which exceeds the health hazard threshold of 1.0 (Table M-18). cis-1,2-DCE (detected in 15 of 20 samples) was the most significant exceedance with a C/SLV ratio of 1.8, all other non-carcinogenic COPCs had C/SLV ratios <1, but several exceeded 0.1, which is the threshold when cumulative HI is greater than 1.

Carcinogenic COPCs - Arsenic, PAHs (direct push), and some chlorinated VOCs were selected as COPCs with a cumulative ELCR of 2.6E-04, which exceeds the risk management range. No SVOCs were identified as COPCs. The COPCs with the highest single chemical C/SLV ratios were arsenic, PCE, TCE and vinyl chloride. However, arsenic in groundwater at the Sandblast Area AOPC was reported at a maximum of 0.0136 mg/L and while this concentration is higher than the Reference Area (0.001 mg/L) (Table I-6), the C/SLV ratio is elevated primarily because of the extremely low SLV (0.000038 mg/L).

COPCs without SLVs – SLVs were available for all preliminary COPCs.

Degradation Products Of PCE – Since PCE was selected as a COPC, its degradation products (dichloroethenes) were also included in the list of COPCs for future consideration, but it should be noted that these degradation products were detected below SLVs.

Summary

There were 13 COIs screened in as COPCs, which consist of metals, PAHs, TPH, and VOCs (Table 11-2). The COPCs contributing the most to health risk at the Sandblast AOPC groundwater for the potable water user include vanadium, arsenic, cis-1,2-DCE, 1,1-DCA, PCE,

TCE and vinyl chloride. The locations where potable water SLVs were exceeded are shown in Figure 11-13. All of the five monitoring well locations had COPC concentrations with exceeding the SLVs by a factor of 10 or more. Arsenic SLVs were exceeded at all locations and the SLVs for VOCs (primarily PCE and TCE) were exceeded at four of the five locations.

11.2.4.2.5 Groundwater - Discharge to Surface Water and Bioaccumulation

Table M-19 provides the results of the comparison of COI data in groundwater against SLVs for the discharge and bioaccumulation pathway. Selected COPCs include metals, PAHs, and VOCs.

The groundwater data were evaluated in relation to the surface water and tissue data for the River OU to assess the potential for release of bioaccumulative COPCs. Results of this pathway screen should be considered along with the River OU results which incorporate tissue data and a broader dataset. Of the metal COPCs, vanadium was selected due to the lack of a bioaccumulation SLV and its bioaccumulation potential has not been evaluated. Concentrations of arsenic in the groundwater were only marginally higher than upgradient arsenic concentrations. It should be noted that the less reliable direct push groundwater data (due to the lack of monitoring well data for PAHs) was used for evaluating the PAHs, which adds to the uncertainty of the relatively low C/SLV ratios for benzo(a)pyrene and indeno(1,2,3-cd)pyrene and the multi-media exposure exceedance of dibenz(a,h)anthracene. Both PCE and vinyl chloride had significant C/SLV ratios of 3.9 and 44, respectively, but VOCs are typically not expected to persist in the water and bioaccumulate. Except for arsenic, the bioaccumulation potential for the COPCs identified was considered to be low since they were not supported by evidence of bioaccumulation in the River OU (Section 11.3.4).

Figure 11-14 shows the locations where the SLVs were exceeded for arsenic. All locations exceeded the bioaccumulation SLV for arsenic by more than a factor of 10. However, the potential for bioaccumulation is best evaluated by review of the River OU data.

11.2.4.3 Pistol Range AOPC

The media sampled at the Pistol Range include soil and groundwater collected by means of direct push sampling and sediment. Based on site history and prior site investigations, the COIs for this AOPC included copper (groundwater and sediment), lead, nickel and zinc in all media.

11.2.4.3.1 On-site Adult Outdoor Worker (0-1.5 ft bgs)

Soil data for the Pistol range were collected from the 0-1.5 ft bgs depth interval, as discussed in Section 5.2.3 and 6.1.3. Table M-21 provides the comparison of soil data for COIs to the SLVs for the Adult Outdoor Worker. For the screening of the Pistol Range AOPC for exposure to soil, the Adult Outdoor Worker is considered protective of both the Construction worker and Excavation worker receptors. The list of COPCs is summarized in Table M-26.

Non-Carcinogenic COPCs - No individual chemical exceeded the corresponding SLV. The cumulative non-carcinogenic C/SLV ratio was also less than 1.0.

The on-site exposure pathways appear to be of low significance for soils and groundwater at the Pistol Range. For on-site receptors, only one COPC, lead, was identified for soil and groundwater at the Pistol Range. The 95% UCL for lead in soil was 365 mg/kg and was lower than the selected SLV of 800 mg/kg (Table M-21). Similarly, the maximum detected concentration of total lead in grab groundwater samples was 0.0125 mg/L which is below the potable use SLV of 0.015 mg/L (Table M-23). The cumulative multi-media C/SLV (1.29) value

was marginally greater than 1.0 (Table M-21). It is highly unlikely that unfiltered groundwater from the area of the Pistol Range AOPC would be used for potable water use. Therefore, no additional consideration of lead is warranted in soil and groundwater for the Pistol Range AOPC and it recommended for no further evaluation.

Carcinogenic COPCs - No carcinogenic COPCs were identified. The cumulative ELCR was 4.2E-09 and is associated with the low concentrations of nickel in soil (Table M-21).

Summary

The only two locations at which the SLV for lead is exceeded are PFR48 and PFR50, where lead concentrations (835 mg/kg and 1,110 mg/kg) are slightly higher than the SLV of 800 mg/kg. These locations are behind the former backstop. Given that lead is not recommended for any further evaluation, these minor exceedances are of low significance and are not a concern for human health.

Construction/Excavation Worker Exposure to Groundwater

As shown in Table M-22, none of the COIs for which SLVs were available for this receptor exceed their SLVs. HI (0.014) and ELCR (4.2E-12) were well below the health hazard and risk thresholds and no COPCs were identified (Table M-26).

Table M-22 shows lead to have a multi-media exposure C/SLV ratio slightly above 1, but lead is not considered a COPC due to low confidence in the SLV used. Lead did not have a DEQ direct contact exposure SLV (exposure to groundwater in a trench) listed and therefore a tapwater SLV was used which still resulted in a C/SLV ratio less than 1.0. If this conservative screen were to be summed with the conservative Adult Outdoor Worker soil exposure (since Construction and Excavation Workers were not screened separately), the multi-media exposure would result in a C/SLV of 1.3. It should also be noted that the DEQ groundwater direct contact SLV was not listed due to the calculated value being above the solubility limit for lead. Given these compelling reasons, lead was not selected as a COPC for this receptor and pathway.

11.2.4.3.2 Groundwater – Potable Water User

In the absence of monitoring well data for the Pistol Range AOPC, groundwater data from the direct-push measurements were reviewed (Table M-23).

Non-Carcinogenic COPCs - The only COPC retained from the direct-push groundwater data was lead. Although lead in groundwater did not exceed the SLVs for potable water use, it was retained on the basis of multi-media exposure in soil and groundwater (Table M-23). No other COPCs were identified (Table M-26).

Although lead was identified as a COPC, it is unlikely that this pathway will constitute a significant health risk since the overall multi-media C/SLV ratio is only marginally higher than 1 (1.29). Use of groundwater form this area, where a very low quantity of perched groundwater is available, is as a potable water source is extremely unlikely.

Carcinogenic COPCs – No carcinogenic COPCs were retained (Table M-26). The cumulative ELCR was 6.9E-08 which is well below the threshold risk level of 1E-06.

In summary, lead is the only possible COPC and due only to multimedia exposure which includes an unlikely scenario of groundwater for potable use. Due to the significant unlikelihood of groundwater at the Pistol Range being used as an unfiltered potable water source and the

marginal exceedance based on multi-media exposure, no further evaluation of lead for this receptor and pathway is warranted.

11.2.4.3.3 Groundwater Discharge to Surface Water and Bioaccumulation

Identification of COPCs for this pathway is shown in Table M-24. Lead screened in as a COPC due to a lack of an SLV. It should be noted lead was not identified as a COPC for the River OU media (Section 11.3.4) and is typically considered to have low potential for bioaccumulation. Therefore, this pathway is unlikely to be of concern for human health and lead was not retained as a COPC that warrants further evaluation..

11.2.4.3.4 Bioaccumulation of COIs from Pistol Range Lagoon Sediments

Off-site exposure pathways are of low significance for the Pistol Range AOPC. Although soils may wash off into the adjacent lagoon, no direct contact pathways related to lagoon sediment are complete for human receptors. Therefore, only bioaccumulation pathways may be complete whereby edible sport fish or their prey may take up COIs that may have washed off into the lagoon.

The metal concentrations in sediment samples collected from the Pistol Range Lagoon were compared to sediment SLVs (Table M-25). Lead and zinc both slightly exceeded their SLV with C/SLV ratios of 2.3 and 1.6 respectively.

Of the four COIs, only lead and zinc are considered potentially bioaccumulative but with low potential (Table J-6). Concentrations of copper and nickel in the adjacent lagoon sediments were comparable to or lower than Forebay area concentrations in sediment. Lead and zinc were slightly higher than Forebay sediments (Table 9-3). None of these COIs were detected in crayfish or smallmouth bass tissue in the Forebay at concentrations that exceed reference area tissue concentrations (Section 8). Neither lead nor zinc has been identified as a COPC in the River OU (Section 11.3.4). Zinc is an essential element that organisms are able to regulate with regard to intake. Thus, there is low potential for bioaccumulation of Pistol Range COIs into aquatic species of interest to human receptors. In the absence of direct contact exposures for sediment in the lagoon, the low bioaccumulation potential for lead and zinc and their low C/SLV ratios, lead and zinc were not do not warrant any further consideration and no further evaluation of these chemicals is warranted for sediments in the Pistol Range lagoon.

11.2.4.4 Bulb Slope AOPC

Surface soil was the only medium evaluated for this AOPC.

11.2.4.4.1 Onsite Adult Outdoor Worker

Six COIs detected in surface soil were compared to their respective SLVs (Table M-27).

Non-carcinogenic COPCs - None of the non-carcinogenic COIs exceeded their SLVs on a single or multi-media basis and the cumulative HI was less than 1.0. Therefore no non-carcinogenic COPCs were identified.

Carcinogenic COPCs - No carcinogenic COPCs were identified since the cumulative ELCR was 1.4E-07 which is below the threshold level of 1E-06. Therefore, no COPCs were identified for this receptor. (Table M-27).

No COPCs were retained for this AOPC. No further evaluation is recommended.

11.2.4.5 All Four AOPCs Combined

Soil and groundwater data from all four AOPCs were pooled to identify COPCs that are relevant to receptors who may be exposed to all the AOPCs. By combining the datasets, the values affected are the frequency of detection rate and the 95% UCL used as the EPC. The primary objective was to identify any new COPCs which were not selected in the individual AOPC screenings. Tables M-28 through M-33 show the screening process. Table M-34 provides a summary of all identified COPCs. No new COPCs (when compared to the individual AOPC COPCs) were identified when considering receptors exposed to all four AOPCs combined.

11.2.4.5.1 Adult Outdoor Worker

The COPC list for this receptor for the combined AOPCs is similar to those identified for the Landfill and Sandblast Area AOPCs.

Non-carcinogenic COPCs - The HI was estimated at 0.12. The COPC list was similar to the COPCs identified for this receptor (Table M-34) for the Landfill AOPC (Table M-12) and Sandblast Area AOPCs (Table M-20).

Carcinogenic COPCs - The cumulative ELCR was estimated at 5.0E-05 (Table M-28). No new COPCs were identified other than those already identified for the individual AOPCs. Arsenic, chromium, PCE and the cPAHs were associated with individual C/SLV ratios that exceeded 1.0 and were retained as COPCs. All other COPCs were identified on the basis of multi-media ratios (lead, TCE, and DRO) or as degradation compounds of PCE and TCE (e.g., dichloroethenes).

In summary, no additional COPCs were retained as COPCs for this receptor (when compared to the COPCs retained for the individual AOPCs).

11.2.4.5.2 Construction Worker and Excavation Worker

Identification of COPCs for these receptors is shown in Table M-29 and M-30. The summary of all initial COPCs is listed in Table M-34..

Construction Worker

Non-Carcinogenic COPCs - The estimated HI was 0.25 and therefore no COI exceeded their respective SLVs. The non-carcinogenic COPCs listed were degradation products of PCE (Table M-29).

Carcinogenic COPCs - The estimated cumulative ELCR was 7.3E-06. PCE and benzo(a)pyrene were the only COPCs with individual C/SLV ratios greater than 1.0 (Table M-29) with all others retained due to degradation products of PCE.

In summary, no new COPCs (when compared to the COPCs retained for the individual AOPCs) were identified with noncancer hazard and cancer risk both below thresholds.

Excavation Worker

Non-carcinogenic COPCs - The cumulative HI is 0.20 (Table M-30) and no COPCs were identified.

Carcinogenic COPCs - The cumulative ELCR was 6.2E-07. and no COPCs were identified.

In summary, no new COPCs were identified with noncancer hazard and cancer risk both below thresholds.

Construction and Excavation Worker Exposure to Groundwater

The identification of COPCs for this pathway is shown in Table M-31. The identified COPCs are summarized in Table M-34.

Non-carcinogenic COPCs - The HI was 3.3 and, while metals and DNOP did not exceed their SLVs on a single medium basis, their C/SLVratios were greater than 0.1 (Table M-31). The elevated HI are completely due to the lack of groundwater direct contact in a trench SLVs and the subsequent use of tapwater values.

Carcinogenic COPCs - The cumulative ELCR was 1E-06 (Table M-31). None of the COIs exceeded their SLVs.

In summary, no new COPCs (when compared to the COPCs retained for the individual AOPCs) were identified.

11.2.4.5.3 Groundwater Potable Water User

The COPC screening process for this receptor is shown on Table M-32. The identified COPCs are listed on Table M-34.

Non-carcinogenic COPCs - The cumulative HI was 11.2 (Table M-32). The primary contributors were manganese and DRO. Because the HI exceeded 1.0, several other COPCs were also identified because their C/SLV ratios were higher than 0.1, per DEQ guidance (Table M-34). However, as discussed for the landfill groundwater, use of residential SLVs to evaluate occupational potable water use is conservative, in addition to the low probability of shallow perched groundwater use as a potable water supply for the Island.

Carcinogenic COPCs - The cumulative ELCR was 2.9E-04 (Table M-32). The ELCR is primarily due to arsenic, chloroform, PCE, TCE and vinyl chloride which were all retained as COPCs.

In summary, no new COPCs (when compared to the COPCs retained for the individual AOPCs) were identified on the basis of screening groundwater data from the combined AOPCs for the potable water use pathways.

11.2.4.5.4 Groundwater Discharge to Surface Water and Bioaccumulation

The evaluation of COPCs is shown in Table M-33. The identified COPCs are summarized in Table M-34. As stated earlier, the River OU better identifies COPCs for this pathway due to the inclusion of tissue data and broader datasets.

There were no new COPCs (when compared to the COPCs retained for the individual AOPCs) from the combined AOPCs for the discharge to surface water and subsequent bioaccumulation pathway.

11.2.4.6 Uncertainty Assessment for Upland OU

Uncertainties are inherent in any risk-based approach to evaluation and decision-making for potentially contaminated sites. The uncertainties may be general and systemic as well as specific to the site. The objective of the uncertainty assessment is to identify the sources of uncertainty in the risk assessment process, understand their potential to contribute to either underestimation or overestimation of risk for the selected receptors and pathways and describe how the uncertainty is addressed. By describing the nature and magnitude of the uncertainties, the findings and

conclusions of the risk assessment can be better understood and used as a tool for decision-making .

The major potential sources of uncertainty in the problem formulation process are associated with the level of confidence in the following:

- identified receptors and exposure pathways, particularly the mass wasting and soil erosion pathway,
- the adequacy of the analytical data used for site characterization,
- SLVs selected for use
- the COPC selection process
- screening-level risk and hazard estimates.

These sources of uncertainty are discussed in detail in the Uncertainty Assessment (Appendix O). In addition, an evaluation of potentially mass wasting and erodible soils at the Landfill AOPC, Sandblast Area AOPC, and Bulb Slope AOPC is presented in Appendix O. Other factors considered include uncertainties associated with COIs eliminated on the basis of frequency of detection and with the statistical background comparison screening.

11.2.5 Conclusions of Problem Formulation - Upland OU

The COPC selection process was performed in the context of the current and reasonably likely future land uses and water uses at the four AOPCs. Of the comprehensive suite of chemical analyses that were performed for soil, groundwater and soil gas samples, the detected analytes were designated as COPCs based on the COPC selection methodology. Tables 11-1 and 11-2 list the COPCs for the AOPCs recommended for risk management at the Upland OU. No additional COPCs were retained based on the all four AOPCs combined evaluation (when compared to the COPCs retained for individual AOPCs).

The evaluation of potentially mass wasting and erodible soils at the Landfill AOPC, Sandblast Area AOPC, and Bulb Slope AOPC is presented in the uncertainty assessment (Appendix O).

11.2.5.1 Landfill AOPC

The Landfill AOPC has exposure pathways that are complete or potentially complete for soil, groundwater, seep water and shoreline surface water for both on-site and off-site receptors. No further evaluation of the Excavation Worker receptor is recommended. The Excavation Worker direct contact exposure to soil (0-10 ft bgs) had acceptable non-carcinogenic hazard and carcinogenic risk and no COPCs were identified. The Construction Worker and Excavation Worker exposure pathway through direct contact to groundwater, likewise had acceptable hazard and risk estimates and no COPCs. These two exposure pathways can be deemed insignificant on the CEM. All other receptors and pathways as shown in the CEM are recommended for further evaluation for this AOPC (see also Table 11-1).

11.2.5.2 Sandblast Area AOPC

Complete or potentially complete exposure pathways related to soil, groundwater and soil gas are noted for the Sandblast Area AOPC. Similar to the Landfill AOPC, the two exposure pathways: Excavation Worker exposure to soil and Construction Worker and Excavation Worker exposure to groundwater, can be deemed insignificant on the CEM. All other pathways and receptors as

shown in the CEM are recommended for further evaluation for the Sandblast Area AOPC (see also Table 11-2).

11.2.5.3 Pistol Range AOPC

The Pistol Range AOPC had a limited number of complete or potentially complete exposure pathways related to surface soil, groundwater, and sediment. Both on-site and off-site pathways were identified. All the receptors and exposure pathways evaluated, except sediment had acceptable non-carcinogenic hazard and carcinogenic risk. Due to the low magnitude of their exceedance and the low likelihood of exposure, lead and zinc were not recommended for any further consideration in lagoon sediment. Because of a marginal multi-media exposure exceedance dependent on the unlikely use of groundwater as a potable water source (Table M-26), lead was not recommended for further consideration in soil or groundwater.. Therefore, the COPCs in the Pistol Range AOPC are not considered to pose a threat to human health. No additional evaluation of this AOPC is warranted.

11.2.5.4 Bulb Slope AOPC

Soil was the only medium of concern identified for the Bulb Slope AOPC with a limited number of potentially complete pathways. No COPCs were identified for this area. None of the COIs exceeded their SLVs at any location and no COPCs were identified. No change in land or water use is likely for this AOPC in the future.

Given the absence of COPCs, the limited number of receptors, exposure pathways and exposure media for the Bulb Slope AOPC, this area is unlikely to pose a threat to human receptors. No additional evaluation of this AOPC is warranted.

11.3 Problem Formulation – River OU

The problem formulation for the River OU focused primarily on the Bonneville Forebay and some of the peripheral areas in the vicinity of the Forebay.

11.3.1 Exposure Setting and Potentially Exposed Populations

Although this portion of the Columbia River is popular with anglers and contact water recreationists, public access to the Forebay and the immediate downstream area is limited. The nearest known fishing platform is located 0.5 mile east of the Forebay, in the Eagle Creek vicinity.

A stakeholder survey was conducted for the Bonneville Dam area (Jones and Stokes 2006). The most popular recreational activities in the area are boating and fishing. Jet-skiing, kayaking, and canoeing were also mentioned as preferred activities by respondents in the survey.

Swimming and wading were not identified as popular activities within the River OU. Anglers are known to wade while fishing near the mouth of Eagle Creek, which is within the backwater area of the dam, and so could have received sediments by current transport. It is also possible that anglers may boat across to Goose Island and fish from the shoreline of the island. Therefore, exposure by direct contact to COPCs in surface water of the Forebay may occur.

Fishing and Fish Consumption Preferences

Since fish consumption is the pathway of greatest interest for the River OU, additional information regarding this pathway is provided in this section. As described in the RI/FS MP

(URS 2007a), several sources of information were consulted to identify suitable fish species for evaluation of the fish ingestion pathway. This identification is important because fish species vary widely in their COPC concentrations as well as in their appeal for human consumption. Factors that may affect the concentrations of COPCs in fish tissue with respect to site-related contamination include resident/anadromous status, home range, trophic level, and lipid content. Surveys of anglers have also shown that different angler groups have different preferences for the species consumed. Abundant resident fish species with small home ranges and high site fidelity are more likely to be exposed to COPCs than anadromous and wide-ranging fish species. Therefore, the data collection and HHRA focused on evaluating risks from consumption of resident fish. The conservative assumptions associated with the resident fish consumption scenario are expected to be sufficient to address risks related to consumption of nonresident fish species as well.

To select the fish species of interest that may have a high degree of exposure to COPCs while at the same time being an edible species of interest to fish consumers, available sources of literature and surveys were consulted. Regional or site-specific studies are preferred since they are expected to be more relevant. For the tribal subsistence fisher, the CRITFC consumption study (CRITFC 1994) provided information on the fish species that are popular with tribal anglers and their consumption rates. The HHRA work plan for Portland Harbor (Lower Willamette Group [LWG] 2004; Agency for Toxic Substance and Disease Registry [ATSDR] 2006) also provided limited information on tribal fish consumption preferences. A recent survey of 43 stakeholders for the Bonneville area was also useful (Jones and Stokes 2006). According to the Bonneville stakeholder survey, the fish species popular with tribal respondents are salmon and sturgeon, while nontribal respondents consumed smallmouth bass and shad. Many, but not all, of the respondents consumed all of the fish caught. Respondents generally fished from a minimum of two to three locations. None of the respondents referred to consumption of shellfish or crayfish from the area.

The Bonneville area is considered to be relatively poor in habitat quality for the popular resident sportfish, due to its high steep banks and lack of vegetated areas and weedbeds (ODFW, personal communication, 2007). It is also unattractive to the general public due to its lack of access, winds and currents (Oregon Bass and Panfish Club 2006). The most popular fishing in this area is for salmon on the Oregon side and sturgeon on the Washington side (ODFW, personal communication, 2007).

Among the species listed, the smallmouth bass is a resident species that is known to occur in the Forebay. It has a small home range and high fidelity to its range and, therefore, has the potential to spend its entire lifetime in the Forebay. It is a trophic level 3/4 species feeding on smaller fish such as sculpin, peamouth, and juvenile fish, as well as crayfish and insect larvae. All these characteristics make it likely that the smallmouth bass is a fish species that may represent maximal exposure to COPCs. It is also extremely popular with sport fishers, nontribal high consumption anglers, and also, to some extent, tribal anglers.

For these reasons, the smallmouth bass was selected as the finfish species that will be used to estimate exposure doses for the fish consumption scenario for all receptors.

At the request of DEQ, an additional fish species (large-scale sucker) is also evaluated but with a higher degree of uncertainty. The large-scale sucker is a fish species belonging to the foraging guild (trophic level 2/3) rather than the carnivorous guild represented by the smallmouth bass. Its

diet consists of phytoplankton and zooplankton, clams, insect larvae, crayfish and oligochaetes. Its home range may be from 0.5 to 10 miles. As discussed in Section 6.2.1, in June and August 2006, the USACE used one sucker composite sample from the Forebay (URS 2008c). The sucker sample is the composite of the five specimens collected from two locations, the south shore of Cascade Island and the south shore of Bradford Island, by the USACE in 2006. The specimens were composited to generate enough tissue mass for analytical testing. The analytical results of the composite sample are included in Table 6-6 and are considered qualitatively in the risk assessments, in Section O (Table O.1-1).

The usefulness of large scale sucker data to evaluate site-related contributions to fish tissue concentrations is limited and subject to a high degree of uncertainty because of its much larger home range and lower site fidelity. The use of and uncertainties associated with use of large-scale sucker tissue data in the HHRA are described in Appendix O.

Although shellfish consumption appears to be relatively minor or minimal, relative to finfish consumption, crayfish were selected as the shellfish species to represent this dietary item. Crayfish are known to occur in the Forebay. They have a large home range and may be exposed to COPCs from sources other than the Forebay. However, they are included in this evaluation to provide a comprehensive estimate of the potential exposure pathways. Consumption of crayfish will be evaluated separately from the consumption of finfish due to the uncertainties involved in whether this pathway is even likely to be complete at the site as well as the home range of the crayfish themselves.

11.3.1.1 Exposure Scenarios

The following human receptors and associated exposure pathways are considered to be potentially exposed to COPCs in the Forebay:

- Adult and child Native American fish harvesters that fish above Bonneville Dam (near the Forebay), who consume potentially contaminated shellfish and finfish at a subsistence level
- Adult and child recreationists who may fish near Eagle Creek who may be exposed to COIs by direct contact with sediments there, and may also consume potentially contaminated shellfish and finfish
- Hypothetical adult or child resident downstream from the dam who could use the Columbia River as a water supply, or whose wells could be recharged from the river

11.3.1.2 Exposure Areas

For the purpose of the problem formulation, exposure areas for the Upland OU (see Section 11.2) and the River OU are defined on the basis of probable exposure by the identified receptors and the nature of the site data. The River OU consists of the Bonneville Forebay, including randomly collected data for the entire Forebay and data collected from targeted areas within the Forebay. Exposure areas are defined for the River OU based on receptor and type of activity, as follows:

Forebay (Random Forebay Samples)

Adult and child Native American fish harvesters and recreational fishers are assumed to consume fish and shellfish that may be exposed to COPCs from the Forebay. Therefore, the Forebay

(excluding Eagle Creek and Goose Island targeted areas) comprises an exposure area for fish and shellfish consumption (as represented by the bass and crayfish random samples). Direct contact with surface water may also occur over the entire Forebay since the fishers most commonly fish by boat.

Mouth of Eagle Creek (Targeted Forebay Samples)

Adult and child recreational fishers fishing from the shoreline at the mouth of Eagle Creek, located along the Oregon side of the Forebay, may be exposed to sediments and surface water by direct contact, if they were to wade in the shallow areas. Therefore, sediments at the mouth of Eagle Creek comprise an exposure area solely for direct contact exposures to sediments within this targeted area.

Goose Island (Targeted Forebay Samples)

The potential for human exposure to Goose Island Slough is limited, although it is accessible to the occasional boater. Edible shellfish and finfish from Goose Island Slough may be part of the bioaccumulation pathway for fishers if they also frequent the rest of the Forebay (Note: the bass collected around Goose Island are evaluated as part of the Random Forebay evaluation).

11.3.2 Conceptual Exposure Model

A CEM for river-related human health risks is presented as Figure 11-15. This CEM focuses on potential risks from contaminated sediments located in the Forebay and near the mouth of Eagle Creek. It also considers the consumption of fish contaminated by sediments and incidental ingestion of, or dermal contact with, river water and sediment. The contact with sediment potentially occurs near the mouth of Eagle Creek. The primary receptors are subsistence fishers, recreational fishers, and hypothetical consumers of unfiltered, untreated river water. As noted earlier, the milk ingestion pathway for infants, described in DEQ's recent Draft guidance, is qualitatively addressed in the Uncertainty Assessment (Appendix O).

11.3.3 Methodology for Identification of COPCs

The process of identification of COPCs for the River OU was similar to the process for the Upland OU and included evaluation of several media (water, sediment, crayfish and smallmouth bass tissue) that were relevant to human receptors. As explained earlier, clam and sculpin tissue were not evaluated for the HHRA since they are not directly consumed by subsistence or recreational fishers.

11.3.3.1 Identification of Contaminants of Interest

The COIs for the River OU include metals, SVOCs, and PCBs and are identified on the basis of chemicals detected in the current datasets that were used to represent the River OU. As previously discussed in Section 11.2.3.1, the COIs are then evaluated further on the basis of three criteria: detection frequency, comparison with reference concentrations (inorganics only), and comparison with risk-based screening levels. The first two steps of the COPC selection process were performed in Section 9.1 (Tables 9-8 through 9-10).

The concentrations of the chemicals retained following the first two steps of the COPC selection process are then compared with risk-based screening levels. The chemicals that fail the HHRA screening process are designated as COPCs and are carried through the risk assessment process. The screening process and the development of the list of COPCs is a critical element of the

Problem Formulation phase of the HHRA. The results of each step of the screening process are described in this section.

11.3.3.2 Detection Frequency

In the first step, COIs that are infrequently detected (less than 5% of samples) may be artifacts in the data due to sampling, analytical, or other errors and need not be selected as COPCs (DEQ 2000, 2010b). However, because none of the River OU media had at least 20 samples, no COIs were removed from COPC evaluation based on detection frequency.

11.3.3.3 Comparison with Reference Area

Similar to the Upland OU, the second step in the COPC screening process involves a statistical (population-to-population) comparison of two independent data sets for each medium was performed between the Reference Area sediment and tissues (crayfish and smallmouth bass) and the random Forebay sediment and tissues, including the 2006 smallmouth bass tissue. Large-scale sucker data were not evaluated with statistical or other quantitative comparisons since only one composite sample is available. As discussed in Section 6.2.1, in June and August 2006, the USACE used one sucker composite sample from the Forebay (URS 2008c). The sucker sample is the composite of the five specimens from two locations that were collected by USACE in 2006. The specimens were composited in order to generate enough tissue mass for analytical testing. The analytical results of the composite sample are included in Table 6-6 and were considered qualitatively in the risk assessment.

The objective of the statistical analysis was to assess whether the mean inorganic COI concentrations in the random Forebay sediment and tissue samples were significantly higher than the mean Reference Area sediment and tissue concentrations. The methodology for this statistical comparison is presented in the Upland OU DSR (URS 2009e). The results of this statistical comparison are presented in detail in Section 8 (Tables 8-3 and 8-4) and Appendix L. The comparison was also performed for organic COIs although it was not used as a factor in selection of COPCs.

For the targeted Forebay sampling locations at Goose Island and Eagle Creek, which do not have enough samples to perform a statistical (population-to-population) comparison, the maximum detected inorganic concentrations in sediment and tissue (clam and crayfish) were compared to the inorganic concentrations in the Reference Area. The results of this comparison are presented in detail in Section 8 and Table L-7 in Appendix L.

The inorganic COIs in sediment and tissue at the Forebay (random and targeted) that were found to not be elevated above the Reference Area were eliminated as COPCs (Section 9.1, Table 9-8 through Table 9-10) . This comparison recognizes that naturally occurring chemicals generally do not need to be addressed in a remedial context if there is no site-related contribution.

11.3.3.4 Concentration-Risk Screen

In the third COPC screening step, the concentration as well as the potential toxicity of the COIs is taken into account by comparing COI concentrations to risk-based screening concentrations that are specific to the media, receptors and pathways that are relevant to the site..

11.3.3.4.1 Selection of Screening Level Values

The human health SLVs used for the River OU evaluation are described in Section 7.3 and listed in Appendix J. The target risk levels and target HQs are similar to the Upland OU SLVs and

correspond to an ELCR of 1 E-06 and non-cancer HQ of 1.0. SLVs were identified for the following media: sediment, surface water, shellfish tissue (crayfish) and finfish tissue (smallmouth bass). The receptors associated with these media included subsistence and recreational fishers and fish consumers and users of river water as a source of potable water.

Some exceptions of note include:

No sediment bioaccumulation SLVs were available for cPAHs in DEQ due to the low frequency and magnitude of their detections in fish in Oregon waters (2010b). The lower of the SLVs (pyrene) for the 2 non-carcinogenic PAHs (fluoranthene and pyrene) was used to evaluate cPAHs in sediment, with the recognition that this may not be sufficiently protective of the cancer endpoint. This issue is further addressed in the uncertainties discussion (Appendix O).

SLVs for PCBs were based on both Total PCBs (as Aroclors and Sum of 209 congeners), TEQ, and the SLVs for the individual dioxin-like congeners.

11.3.3.4.2 Application of Screening Level Values

The concentration-risk screen approach for the River OU was generally similar for the River OU and the Upland AOPCs. It included the two-step process of screening a COI on the basis of exposure to single chemicals, multiple chemicals, and multiple media. However, there were some differences among media and pathways.

Exposure to Individual COIs – Carcinogens and Non-carcinogens

Single COIs that exceeded the appropriate SLVs (i.e., C/SLV > 1.0) were retained as COPCs if they met the conditions described below.

Direct Contact Pathways

Surface Water COIs in surface water for the Forebay were retained as COPCs if the C/SLV exceeded 1.0 using SLVs applicable to potable water use (e.g., drinking WQC, tap water RSLs).

Sediment There are no SLVs based upon protection of direct contact exposures to sediments. Therefore the C/SLV ratio could not be estimated. All COIs in Eagle Creek sediments were retained as COPCs for the direct contact pathway for waders, with the exception of inorganic COIs that were observed at concentrations similar to or lower than Reference Area sediments.

Bioaccumulation Pathways

Tissue COIs in crayfish and smallmouth bass from the Forebay were evaluated by comparison to SLVs for tissue consumption. Inorganics typically had detected frequencies of 100% in tissue and were retained if they exceeded reference tissue values.

Surface Water COIs in water media were first evaluated by comparison to available federal or state WQC for the consumption of organisms or organism + water and subsequently by their bioaccumulation potential. Bioaccumulative COIs without organism-based WQC were reviewed further. Non-bioaccumulative COIs without SLVs were eliminated.

Sediment Only tissue COPCs evaluated in sediment were compared to sediment bioaccumulation SLVs. Inorganics were also compared to reference sediment values. To be conservative and comprehensive, COIs that did not exceed sediment SLVs were retained as COPCs if they were already selected as tissue COPCs.

For all the single COI pathways, each form of PCB results (individual Aroclors, Total PCBs as Aroclors, Total PCBs as Sum of 209 congeners, PCBs as TEQ, and individual dioxin-like congener) was compared to an appropriate SLV.

Exposure to Multiple COIs in a Single Medium

COIs that did not exceed their individual SLVs but whose C/SLV ratios exceeded 0.1 were retained as COPCs if the sum of the individual ratios in surface water, tissue or sediment exceed 1.0, with some exceptions. The ratios were separated into the sum of the non-carcinogenic C/SLV ratios and sum of the carcinogenic C/SLV ratios. To avoid double-counting the ratios of PCBs which were reported in multiple forms, only the ratios associated with the 12 dioxin-like congeners were included in the Sum carcinogenic C/SLV value (cumulative ELCR).

Multimedia Exposure to a Single COI

The multiple media in the River OU include sediment, water, and tissue. Multimedia exposure scenarios include anglers who may wade in the sediments near Eagle Creek while consuming crayfish and smallmouth bass from the Forebay at subsistence levels of consumption and also using untreated river water as a potable water supply source.

COPCs without SLVs - COPCs without SLVs were evaluated further with respect to spatial trends and frequency of occurrence.

COPCs - The list of COPCs for each medium was further evaluated based on the process outlined above. The COPCs were then reviewed with regard to the basis of the designation, magnitude of their exceedances above SLVs, spatial distribution, and the relevant receptors and exposure pathways. Note that all tissues are evaluated on a whole body, wet weight basis.

11.3.4 Screening Level Risk Characterization

This section describes the results of the COPC identification and screening-level risk results for the River OU.

11.3.4.1 Forebay

The media evaluated for the Forebay included sediment, surface water, crayfish tissue and smallmouth bass tissue.

11.3.4.1.1 Subsistence Fishers

The media that may contribute to risk to the subsistence fisher include crayfish tissue and smallmouth bass tissue, which would be consumed directly. The tissue data were the primary line of evidence to select COPCs for the finfish and shellfish consumption pathway. The sediment data were evaluated to select bioaccumulative COPCs that might be taken up by shellfish and finfish.

Identification of COPCs for this receptor is presented in Tables M-35 for the tissue data and Table M-36 for the sediment data. Table M-46 presents a summary of the identified COPCs by medium.

Crayfish Tissue

For subsistence fishers, after the elimination of COIs based on comparison to Reference Area tissue (inorganics only) and concentration-risk screen ratios, the selected COPCs for crayfish

tissue included only carcinogenic COPCs (Table M-35). These COPCs may warrant further evaluation in shellfish consumption pathways for subsistence-level fish consumers.

Non-carcinogenic COPCs – No non-carcinogenic COPC was identified either on a single-medium or multi-media basis. The cumulative HI was 0.67 (Table M-35). Therefore, non-carcinogens are not of concern.

Carcinogenic COPCs – The cumulative ELCR was 7.5E-04, primarily due to arsenic and PCBs (Table M-35). The ELCR reported for crayfish consumption should be interpreted with caution. Crayfish may live to 5 or 6 years and often may live as long as 10 years (URS 2007a). Therefore, although the Forebay Random crayfish were collected after the sediment removal action, they are very likely to have had exposure to pre-removal concentrations of Forebay COPCs for several years prior to their sample collection. Thus this ELCR does not represent current Forebay exposures for crayfish.

As shown on Figure 11-16, exceedances of the PCB and arsenic SLVs occurred in almost all the crayfish samples. These COPCs are discussed further below.

Arsenic

Arsenic was retained as a COPC because it was higher than in the Reference Area crayfish (Table 8-3). However, this is more a measure of the precision of the data and the sensitivity of the comparison than actual differences. Although arsenic had a relatively high C/SLV ratio (683, the 95% UCL for arsenic in Forebay crayfish tissue (0.519 mg/kg; Table M-35) was actually slightly lower than the Reference Area 95% UPL of 0.535 mg/kg (Table I-20). The range also is very similar with the Forebay random crayfish concentrations ranging from 0.380 to 0.680 mg/kg (Table I-8) and the Reference crayfish ranging from 0.275 to 0.636 mg/kg (Table I-11). The mean concentration in Forebay crayfish was 0.479 mg/kg compared to 0.383 mg/kg for the Reference area (Tables I-18 and I-20). Therefore, the potential for contributions from the Forebay to arsenic in crayfish tissues is low.

The SLV for arsenic is based on the assumption that all of the arsenic is inorganic which is the most toxic form of arsenic for humans. In reality, the majority of the arsenic in fish and shellfish tissue is likely to undergo methylation into the less toxic organic form. Although estimates of inorganic arsenic as a fraction of total arsenic that are specific to freshwater crustaceans and mollusks are not available, recent reviews have estimated that inorganic arsenic may typically constitute less than 10% of total arsenic in freshwater finfish, but may range up to 30% in contaminated sites (Lorenzana et al 2009). These and other authors do not make a distinction between finfish and shellfish regarding the speciation of arsenic and they are presumed to be similar (Schoof et al 2007). Estimates of the organic portion of the arsenic body burden of shellfish tissues in the Columbia River range from 0.1 to 27% (TetraTech 1996). Using an estimate of 10 to 25% of total arsenic as inorganic arsenic would result in C/SLV values of 68 to 170 for the subsistence fisher.

The fish ingestion rates used in the development of the acceptable tissue levels (ATLs) for subsistence fishers (142 g/day) are higher than the assumed rates for recreational fishers (17.5 g/day). In the approved RI/FS MP (URS 2007a), it was noted that consumption of shellfish from the Bonneville Forebay was not known to occur, particularly for subsistence fishers, and evaluation of subsistence-level consumption of shellfish is not proposed for further evaluation.

The highest concentrations of arsenic in crayfish tissue were noted in two samples in the vicinity of the south shore of Cascades Island and north shore of Bradford Island (Figure 11-16). The highest concentration 0.680 mg/kg from location P2-CF (Table 6-10) was only marginally higher than the Reference Area 95% UPL of 0.535 mg/kg (Table I-20).

Given the low potential for shellfish consumption by subsistence fishers in the Forebay, and the fact that much of the arsenic in tissue is likely to be in the less toxic form, it is concluded that the potential is low for arsenic to pose a significant risk through the shellfish consumption pathway.

PCBs

The C/SLV ratios for total PCBs and individual congeners ranged from a low of 0.018 (Congener 81) to a high of 64.0 (Total PCBs as Congeners) (Table M-35). Of the six dioxin-like congeners, congeners 118, 126 and 156+157 have the highest C/SLV ratios. Among these, the C/SLV ratio for Congener 126 is similar to the ratio for Reference crayfish and illustrates that not all congeners are uniformly elevated in the Forebay. The highest ratio corresponds to an approximate ELCR of 6.4E-05. This falls within USEPA's risk management range although it exceeds DEQ's target risk level of 1E-05 for total risk.

The SLV for total PCBs was exceeded in almost all the crayfish samples (Figure 11-16). The highest PCB concentrations were measured in crayfish samples collected from the north shore, south shore and eastern tip of Bradford Island, where the SLV was exceeded by more than an order of magnitude. Total PCBs and several dioxin-like congeners were significantly higher in Forebay Random crayfish when compared to Reference crayfish.

COPCs without SLVs All COIs had SLVs available.

Summary

In summary, arsenic and PCBs were retained as COPCs for this receptor (Table 11-3). As illustrated in Figure 11-16, exceedances of the PCB SLV were evident in most of the crayfish samples.

Smallmouth Bass Tissue

Using a process similar to that used for crayfish, the COPCs identified for smallmouth bass tissue included barium, mercury, PCBs (Aroclor 1242, Aroclor 1254, Total PCBs and all dioxin-like congeners), B2EHP, and five cPAHs (Table M-35) and are summarized in Table M-46. The COPCs are summarized in Table 11-3.

Non-carcinogenic COPCs - Barium screened in as a COPC based on cumulative exposure, but individually, its C/SLV ratio of 0.44 was less than 1.0 and it is unlikely to contribute significantly to non-cancer hazard. Mercury was the only non-carcinogenic COPC retained based on its individual C/SLV ratio of 6.47 (Table M-35). It was detected in all Forebay bass samples and exceeded Reference Area concentrations (Table 8-3). It may be reliably assumed that almost all the mercury detected in bass tissue is likely to be present in its more toxic form as methyl mercury. Smallmouth bass are known to be consumed by subsistence and recreational fishers.

The Forebay UCL for mercury was 0.317 mg/kg (Table I-18), in comparison to the Reference Area 95% UPL of 0.268 mg/kg (Table I-20). The range of mercury concentrations in Forebay smallmouth bass was 0.0710 mg/kg to 0.512 mg/kg (Table I-8) while the range in Reference bass was 0.0548 mg/kg to 0.333 mg/kg (Table I-11). The two highest concentrations were found in a sample collected near the eastern tip of Bradford Island (18) and a sample collected in the

vicinity of Goose Island (13) (Figure 11-16). Mercury concentrations in sediment are not significantly different between the Forebay and Reference areas (Table 8-3).

Finally, the C/SLV ratio for the Reference area smallmouth bass for mercury, based on the UPL, is 5.47 compared to the Forebay C/SLV of 6.47, i.e., there is an incremental increase of a HQ unit of 1.0 between the Forebay bass and Reference area bass. This small difference may be due to variability in the data or may represent mercury from non-site-related sources since the mercury concentrations in sediments are similar.

Carcinogenic COPCs - As shown in Figure 11-16, exceedances of one or more COPCs were noted in all bass samples. B2EHP, PCBs, and some cPAHs are retained as COPCs and discussed further below (Table M-46). The cumulative ELCR was 3.4E-02, however, this value is highly uncertain and misleading due to the uncertainties in the PCB data for smallmouth bass, the major uncertainty being that the bass were collected prior to the interim removal action of 2008 and their tissue concentrations probably reflect uptake from an earlier period when PCB concentrations in the Forebay were higher. Therefore, this ELCR does not represent current conditions in the Forebay smallmouth bass to an even greater degree than the crayfish tissue data. This is discussed in more detail in Appendix O.

A wide variation in PCB concentrations (as Aroclors, total PCBs and as individual congeners) were observed in the smallmouth bass. Total PCBs as well as all the individual dioxin-like congeners are associated with elevated C/SLV ratios for all smallmouth bass samples. However, the magnitude of exceedances ranged over five orders of magnitude. Additional evaluation, monitoring or risk management of PCBs as COPCs for smallmouth bass tissue is warranted (Table 11-3).

B2EHP and five cPAHs were identified as COPCs because the single chemical C/SLV ratios exceed 1.0 (Table M-35). The magnitude of exceedance was relatively small and was generally less than a factor of 4. Consistent with DEQ guidance, all the cPAHs are retained as COPCs even if individual cPAHs did not exceed their SLVs.

The UCL for B2EHP in Forebay bass was 349 µg/kg, with concentrations ranging from 89 to an outlier sample that was reported at 1600 µg/kg (Table I-8). The UPL (based on maximum) and range for the Reference area fish was 150 µg/kg (Table I-20) with a range of concentrations of 81 µg/kg to 150 µg/kg (Table I-11). The ELCR associated with B2EHP is approximately 4E-06 (Table M-35). However, B2EHP had a relatively low detection frequency in Forebay bass tissue (37%) (Table I-8a). Of the seven detections, six samples had concentrations ranging from 89 µg/kg to 190 µg/kg which are generally similar to the Reference Area 95% UPL of 150 µg/kg. The relatively low concentrations detected in fish tissue supports the position that these compounds are readily metabolized and only weakly bioaccumulate (similar to the metabolic action noted in PAHs). At other contaminated sediment sites, including the Lower Duwamish Waterway, phthalates often occur with other compounds (e.g., PCBs) that dominate risk. The phthalates are typically overshadowed by these more potent risk-drivers (Sediment Phthalate Work Group 2007).

Among the five cPAHs selected as COPCs, benzo(a)pyrene and dibenz(a,h)anthracene had the highest ratios. However, whether any of the cPAHs are likely to pose a threat to human health is uncertain. PAH levels in fish are usually low because this group rapidly metabolizes PAHs (Lawrence and Weber 1984); furthermore, higher molecular weight PAHs, which include the largest class of chemical carcinogens, do not seem to accumulate in fish (West et al. 1984). In

general, free (unmetabolized) PAHs are detected at lower concentrations in muscle than in liver, gonads, stomach, or gall bladder (bile), although liver concentrations are probably more associated with short-term exposure and muscle concentrations are probably more associated with long-term bioaccumulation (Hellou 1996). Whether the PAHs in the smallmouth bass are present in the edible portions of the fish such as muscle, or in the portions that are discarded during cooking (e.g., viscera) is unknown since the smallmouth bass data for the Forebay are based on whole-body analyses. Although the Forebay smallmouth bass had higher concentrations of cPAHs than Reference Area bass, this trend was not observed in sediments (Table 8-3). Therefore, the occurrence of higher PAH concentrations in Forebay bass cannot be definitively attributed to sources in Forebay sediments.

COPCs without SLVs - SLVs were available for all COIs.

Summary

In summary, metals, B2EHP, cPAHs, and PCBs were retained as COPCs for this receptor (Table 11-3), with PCBs posing the greatest risk.

Sediment

COIs in Forebay sediment were evaluated only for the bioaccumulation pathway since the water depths make direct contact with these sediments highly unlikely for human receptors. Only COIs detected in tissue were retained and inorganics were also compared to reference sediment values. As described earlier, all sediment COIs were retained as sediment COPCs if the same COIs in tissue exceeded tissue ATLs for either crayfish or smallmouth bass. COPCs for sediment were also identified if the C/SLV ratio exceeded 1.0. The list of COPCs is summarized in Table M-46.

Non-carcinogenic COPCs - No non-carcinogenic COPCs were retained since both single medium and multi-media ratios were less than 1.0 for all non-carcinogenic COIs (Table M-36). However, mercury was selected as a COPC, even though it is comparable to Reference Area concentrations, because it is a bioaccumulative chemical that has been retained as a tissue COPC for smallmouth bass. But any contribution from Forebay sediments to tissue mercury levels is likely to be minor.

Carcinogenic COPCs - The cumulative ELCR was 7.5E-05 (Table M-36). The COPCs identified in sediment for bioaccumulation included PCBs (Aroclor 1254, Total PCBs as Aroclors, 6 congeners, Total PCBs as Congeners and Total PCBs as mammalian TEQ) and B2EHP, = (Table M-45). The single chemical C/SLV ratios for PCBs were far lower in sediments than in smallmouth bass. This is likely due to the fact that the sediment samples were collected after the sediment removal action and are more representative of current conditions in the Forebay. In contrast, the smallmouth bass samples were collected prior to the sediment removal and represent historical conditions. The sediment C/SLV ratios ranged from 7.45 to 598 (for Total PCBs as Aroclors), corresponding an approximate ELCR range of 7E-11 to 6E-04 for subsistence fishers. However, when the more accurate estimate of PCB sums (sum of dioxin-like congeners) was used, the cumulative ELCR was 7.5 E-05. This falls within the risk management range.

Bioaccumulation SLVs are available for two non-carcinogenic PAHs, fluoranthene, and pyrene. The lower of the two, the SLV for pyrene, was used to screen all the other individual PAHs. All C/SLV ratios were several orders of magnitude lower than 1.0.

COPCs without SLVs - B2EHP, was identified as a COPC without SLVs (Table M-35). It was also reported in only three of 19 sediment samples, at concentrations of 0.3 mg/kg or less (Table I-18).

Summary

PCBs, mercury and B2EHP are the only COPCs retained for sediment (Table 11-3) with PCBs being noteworthy based on significance of exceedance. The locations of SLV exceedances for sediments are shown in Figure 11-16. All sediment samples have SLV exceedances for total PCBs, primarily because of the extremely low SLV for subsistence fishers.

11.3.4.1.2 Recreational Fisher

The recreational fisher is assumed to consume both finfish and shellfish from the Forebay, but at lower rates of consumption than the subsistence fishers. In DEQ's assumptions, the recreational fisher's fish consumption rate is about 12% of the subsistence fisher's rate. Therefore, the C/SLV ratios for this receptor are about eight-fold lower. The comparison of COPCs to SLVs is shown in Table M-37. The identified COPCs are listed in Table M-46.

Crayfish Tissue

Non-carcinogenic COPCs - No non-carcinogenic COPCs were retained since the HI was 0.08 and no multi-media ratios exceed 1.0 (Table M-37). The locations of SLV exceedances are shown on Figure 11-17. The majority of the exceedances were for arsenic with fewer locations having significant exceedances for PCBs.

Carcinogenic COPCs – The cumulative ELCR is estimated at 9.2E-05 (Table M-37). Similar to the case of the subsistence fisher and to an even greater degree, arsenic is unlikely to contribute to significant risk for the recreational fisher. Using the arsenic ATL for recreational fishers (0.0062 mg/kg) results in C/SLV ratio of 83.7. Further, assuming 10 to 25% inorganic arsenic fraction would result in C/SLV ranges from 8.3 to 21. Finally, since the Forebay average for arsenic is comparable to the Reference Area average as discussed in the evaluation of the Subsistence Fisher, and should be considered with arsenic's selection as a COPC for the recreational fisher.

The C/SLV ratios for PCBs for recreational fishers are substantially lower than for subsistence fishers and fall within a risk range between 1E-06 and 1E-05. Using the ATL for recreational fishers (0.0047 mg/kg) results in a C/SLV ratio of 7.8 (approximate ELCR of 8E-06). DEQ applies an acceptable cumulative risk level of 1E-05 to multiple congeners as well as to total PCB measurements based on sum of congeners (DEQ 2010b). Using this standard, PCBs in Forebay crayfish tissue fall within acceptable risk levels for recreational fishers according to both USEPA and DEQ guidance. Nonetheless, PCBs were retained as COPCs.

COPCs without SLVs – All COIs had SLVs available.

Summary

Arsenic and PCBs were retained as the COPCs for this receptor (Table 11-3). The spatial distribution of concentrations is illustrated in Figure 11-17.

Smallmouth Bass Tissue

Non-carcinogenic COPCs – Similar to the subsistence fisher, barium and mercury are COPCs based on their cumulative health hazard, though they individually had C/SLV ratios less than 1.0 (Table M-37).

Carcinogenic COPCs - The Smallmouth Bass COPCs for the recreational fisher included PCBs, benzo(a)pyrene and dibenz(a,h)anthracene (Table M-37). The cumulative ELCR is 4.1E-03, a misleadingly elevated value that is dominated by the ratios for PCB congeners 118 and 126. Among these, the cPAHs are unlikely to contribute significant risk to this receptor due to their low C/SLV ratios. The ratios for the two cPAHs were less than 10, indicating that the associated risk levels are less than 1E-05. The C/SLV ratios for PCBs ranged from one to four orders of magnitude higher than the SLVs. Therefore, the primary risk contributors for recreational fishers are PCBs. The locations of SLV exceedances are shown in Figure 11-17 and include most of the bass samples.

COPCs without SLVs - All COIs had SLVs available.

Summary

The COIs retained as COPCs were metals, PCBs and cPAHs (Table 11-3).

Sediment

Sediment COPCs for the bioaccumulation pathway were identified based on comparison to bioaccumulation SLVs and detection in tissue COPCs (Table M-38).

Non-carcinogenic COPCs – No non-carcinogenic COPCs were selected. The HI was below 1.0 and no multi-media ratios exceeded 1.0.

Carcinogenic COPCs – The cumulative ELCR was estimated at 9.2E-06. As was the case for the smallmouth bass, PCBs were the primary risk-driving COPCs in sediment for the recreational fisher. The highest C/SLV ratios were associated with Aroclor 1254, Total PCBs as Aroclors, Total PCBs as Congeners, congeners 118 and 126 and Total PCBs as Mammalian TEQ. The ratio for Total PCBs as Aroclors was 73.6 , and for Total PCBs as Congeners was 9.19, corresponding to screening risk levels of 7E-05 and 9E-06, respectively. These values slightly exceed the acceptable risk level when Aroclor 1254 is considered in isolation, but fall within the acceptable risk range for Total PCBs. Greater confidence is placed in the PCB data for congeners than for Aroclors.

COPCs without SLVs – All COIs had SLVs available.

Summary

COIs that were retained are PCBs (Table 11-3). As shown in Figure 11-17, the locations with PCB C/SLV ratios greater than 10 were generally along the north shore of Bradford Island, adjacent to were the sediment removal took place. PCB concentrations in the majority of the sediment sample locations along the south shore of Bradford Island and in the vicinity of Goose Island had total PCB concentrations which exceeded the SLV by a factor of less than 10.

11.3.4.1.3 Hypothetical Potable Water Use and Water-Based Bioaccumulation

Surface water data were evaluated for a hypothetical resident who may use river water for potable water use and also consume fish from the Forebay.

Overall, only a few COPCs were retained in surface water for either the potable water use or bioaccumulation pathways (Tables M-39 and M-40, respectively).

Potable Use/ Direct Contact

Non-carcinogenic COPCs – No non-carcinogenic COPCs were retained.

Carcinogenic COPCs - The evaluation of surface water COIs for the potable water use-related pathways resulted in the selection of arsenic and PCBs and a few cPAHs as COPCs (Table M-39). The cumulative ELCR was 2.7E-05 (Table M-45). The C/SLV ratios were two to three orders of magnitude below 1.0 for all chemicals except arsenic.

The levels of total PCBs and the individual congeners and cPAHs were associated with single-medium C/SLV ratios three to four orders of magnitude lower than 1.0. They were identified as COPCs only on the basis of multi-media ratios that are influenced by the bioaccumulation pathway. PCB concentrations in Forebay surface water were very similar to Reference Area ranges (Table M-40). In practice, it is unlikely that PCBs in surface water would contribute significantly to risk.

Summary

In summary, arsenic, PCBs, and cPAHs screened in as COPCs for this pathway. As shown in Figure 11-18, all the five sample locations for surface water had SLV exceedances for arsenic and PCBs.

Bioaccumulation

Comparison of surface water data to bioaccumulation SLVs is shown in Table M-40. The summary of identified COPCs is presented in Table M-45.

Non-carcinogenic COPCs – No non-carcinogenic COPCs were retained due to exceedance to SLVs since the HI was well below 1.0.

Carcinogenic COPCs – Only arsenic and PCBs were identified as COPCs for the bioaccumulation pathway for surface water (Table M-40). Arsenic was retained as a COPC because the C/SLV ratios was greater than 1.0 (56.1). PCBs were retained because total PCBs C/SLV ratio was approximately 3.3, indicating an associated screening level risk of 3E-06.

COPCs without SLVs – Aluminum and lead did not have bioaccumulation-based SLVs.

Summary

In summary, metals and PCBs were selected as COPCs for this receptor (Table 11-3).

11.3.4.1.4 Wader at Mouth of Eagle Creek

Sediments were collected from two locations at the mouth of Eagle Creek to represent the potential for direct contact pathways for waders. There are no readily available SLVs for evaluation of direct contact pathways for sediments. As a result, with the exception of inorganic COIs that were not higher than reference area sediments, all other COIs in Eagle Creek sediments were retained as COPCs for the direct contact pathway (Table M-41). These included Aroclor 1248, Total PCBs as Aroclors, carbazole, most PAHs, and DRO.

Non-carcinogenic COPCs - All non-carcinogenic metals were lower than in the Reference Area sediments (Tables L-7 and M-41). Several non-carcinogenic PAHs were detected at low

concentrations (Table M-41). Discussion of the significance of these PAHs is included with the cPAHs below.

Carcinogenic COPCs – Of the COPCs, Aroclor 1248 Total PCBs as Aroclors, carbazole and a few PAHs had concentrations that were slightly higher in Eagle Creek sediments than in Reference sediments (Table L-7). Although there are no direct contact SLVs for PAHs in sediments, it is notable that all the PAHs, both carcinogenic and non-carcinogenic, in Eagle Creek sediments were lower than the soil SLVs for occupational worker and were even lower than the residential SLVs (DEQ 2010). For example, the DEQ SLV for benzo(a)pyrene in residential soil is 15 µg/kg. This is the most potent of the cPAHs. The maximum values of all PAHs in Eagle Creek sediments ranged from 1.1 to 17.0 µg/kg (Table M-41). Since only direct contact pathways are envisaged at Eagle Creek, the use of the soil SLVs provides a reasonable substitute for the lack of sediment SLVs. Although PAHs are not expected to significantly contribute to risks for waders in the Eagle Creek sediments, they were retained as COPCs.

COPCs without SLVs - As a proxy for sediment, soil-based screening concentrations were derived for carbazole using the standardized USEPA (2010) input values for residential (24 hrs per day, 350 days per year, 6 years as a 15 kg child and 24 years as a 70 kg adult) and commercial/industrial (8 hrs per day, 250 days per year for 25 years as a 70 kg adult) exposure scenarios. For the residential scenario, the USEPA's method of childhood-only exposure (USEPA 2010) resulted in a slightly less stringent screening concentration. Exposure was assumed to occur through incidental ingestion, dermal contact, and particulate inhalation, also using standardized Department of Toxic Substances Control (DTSC) or USEPA factors for skin surface area, skin adherence factors, the particulate emission factor, and oral and dermal absorption factors (USEPA 2010). The toxicity factor was an oral slope factor $(0.02 \text{ mg/kg-day})^{-1}$, based on liver tumors in mice fed carbazole in the diet for 96 weeks (as cited in USEPA 1997c). The screening concentrations were derived to meet a target cancer risk level of 1E-06. Based on carcinogenic effects, the screening concentration for the residential receptor is 24 mg/kg and is 67 mg/kg for the commercial/industrial receptor. The detected concentration of carbazole (2.2 µg/kg) was orders of magnitude lower than the SLV.

Summary

All COIs were retained (except for metals below reference and carbazole) as COPCs of which PCBs as Aroclors is noteworthy based on the significance of exceedance. PCBs were also identified for Eagle Creek sediments higher than in the Reference sediments (Table 11-3).

11.3.4.2 Goose Island Slough

Collection and evaluation of sediment and tissue samples from Goose Island Slough was not included in the RI/FS MP (URS 2007a) but was conducted at DEQ's request (URS 2009k). Although there are no barriers restricting public access to Goose Island Slough, direct contact with sediments in this area for human receptors is highly unlikely due to the depth of the slough and the rocky banks. The COIs detected at Goose Island were evaluated as follows:

Crayfish tissue

Metals, PCBs, and PAHs were detected in crayfish tissue. However, all the COIs were generally detected at concentrations that were lower than in crayfish tissues from the Forebay. Inorganics were generally lower than in reference area crayfish tissue (Table L-7). Therefore, only PCBs were identified as COPCs based on Goose Island crayfish tissue (Table M-42).

Smallmouth Bass Tissue

All smallmouth bass tissue samples collected in Goose Island Slough were included in the Forebay tissue data set. Therefore, no additional COPC selection for bass for Goose Island was necessary.

Sediment

Metals, PCBs, PAHs and phthalates were detected in Goose Island sediment. However, the majority of the COIs were generally detected at concentrations that were lower than in sediment from the Forebay (Table L-7). The COPC selection results for the two targeted Goose Island sediment samples are already included in lists for the subsistence and recreational fishers (Tables M-43 and M-44). Inorganics were generally lower than in reference area sediment (Table L-7). A few PCB congeners were detected at concentrations exceeding the Reference Area (Table L-7) but were not comparable to or less than Forebay concentrations. B2EHP screened in due to the lack of an SLV. Therefore, B2EHP and PCBs were identified as COPCs based on Goose Island sediment data.

Summary

In summary, PCBs were the COPCs identified in crayfish tissue and B2EHP and PCBs were the COPCs identified in sediment from Goose Island (Table 11-3), of which PCBs are noteworthy based on significance of exceedance.

11.3.4.3 Uncertainty Assessment

The major sources of uncertainty for the problem formulation process for the River OU include the level of confidence in the following:

- Occurrence and magnitude of exposure pathways and receptors, particularly for subsistence fisher and hypothetical use of river water as potable water supply
- Quality of analytical data for analytes occurring at low concentrations
- Representativeness of tissue data
- COIs without SLVs
- Screening-level risk and hazard estimates

Each of these factors is discussed in more detail in the Uncertainty Assessment (Appendix O). Other factors considered include the uncertainties associated with COIs eliminated on the basis of frequency of detection.

11.3.5 Conclusions of Problem Formulation – River OU

11.3.5.1 Forebay

The media evaluated for COPC selection for the Forebay included surface water, crayfish tissue, smallmouth bass tissue, and sediment. Clam and sculpin tissue were not considered relevant because the species are not consumed by humans. Data from the single large-scale sucker sample was not directly evaluated, but a comparison of the data to smallmouth bass data revealed that the addition of large-scale sucker data to a quantitative evaluation (in addition to smallmouth bass) is not likely to add either precision or accuracy to the risk estimates, and will not result in underestimation risk. The receptors of concern were subsistence and recreational anglers, potable

water users and waders near the mouth of Eagle Creek. The results are discussed by receptor and then media below, and the COPCs recommended for risk management are summarized in Table 11-3.

Subsistence Fisher

Carcinogenic risks to the subsistence fisher may exceed USEPA's and DEQ's acceptable risk levels in the screening level problem formulation. The risks are associated primarily with consumption of smallmouth bass tissue, and secondarily, crayfish tissue. Fish consumption risks estimated on the basis of sediment data are lower than those estimated using tissue data. The greatest uncertainty is in the use of tissue data that include exposure to pre-removal conditions.

Recreational Fisher

The exposure pathways for the recreational fisher include ingestion of fish and exposure to sediment via direct contact. PCB risks to this receptor from sediment fall within the risk management range (Table M-38). Risks to this receptor from fish and shellfish ingestion range from unacceptable to falling within the risk management range for this receptor.

Surface Water User

The exposure pathways for surface water included potable water use and bioaccumulation (i.e., consumption of fish exposed to bioaccumulative COPCs in water). The organic COPCs, PCBs and cPAHs, are expected to be negligible contributors to risk due to the lack of exceedance of their individual SLVs. Therefore, risks associated with these COPCs in surface water are likely to be at acceptable risk and hazard levels for the potable use and bioaccumulation pathways of exposure.

11.3.5.1.1 Surface Water

Only a few COPCs were retained in surface water for either the potable water use or bioaccumulation pathways (Table 11-3). PCBs and arsenic are the main surface water COPCs that may influence tissue bioaccumulation pathways.

In summary, the detected COPCs in surface water of the Forebay is not expected to pose a significant risk for the potable user and as a transport pathway for bioaccumulation to edible fish and shellfish.. This conclusion is based on the limited number of COPCs identified in Forebay surface water, the similarity to Reference Area concentrations and the lack of exceedance of the associated SLVs.

11.3.5.1.2 Tissue

Two types of edible tissue were evaluated for the human health problem formulation: crayfish and smallmouth bass. This tissue discussion focuses on the subsistence user results.

Crayfish

The COPCs retained for crayfish tissue include arsenic and PCBs (Table 11-3). The screening-level risk estimates developed on the basis of crayfish tissue are likely to overestimate risks since the crayfish are likely to have been exposed to COPCs under pre-removal conditions in the Forebay.

Smallmouth Bass

The primary COPCs for smallmouth bass are PCBs, and secondarily mercury and cPAHs (Table 11-3). The major uncertainty associated with smallmouth bass data relates to whether the data are representative of current conditions. The samples were collected prior to the removal of PCB-contaminated sediment from the Forebay. Therefore, the data represent exposures to higher PCB concentrations in sediment and prey than are present currently. Tissue concentrations in bass hatched after the sediment removal are likely to be lower and would be more reflective of current conditions. It is likely that cPAHs may be minor contributors to risk if data regarding their distribution in the edible portions of fish tissue were available.

11.3.5.1.3 Random Forebay Sediment

The COPCs for sediment in the Forebay were selected on the basis of potential for bioaccumulation into the food-web with ultimate exposures to subsistence and recreational fishers. The COPCs were selected on the basis of two major criteria: exceedance of the bioaccumulation SLVs for sediments, and selection as tissue COPCs for either crayfish or smallmouth bass. COPCs for sediment include only PCBs (Table 11-3). B2EHP was also identified as a COPC due to the lack of a sediment bioaccumulation SLV.

11.3.5.2 Mouth of Eagle Creek

Only organic compounds were selected as COPCs for Eagle Creek sediments (Table 11-3). With the exception of Aroclor 1248, concentrations of all other COPCs such as carbazole, PAHs, and DRO were lower than or only marginally higher than concentrations in Reference Area sediments. Therefore, risks related to direct contact with sediments for waders are unlikely to be contributed from the Forebay, and are likely to be relatively low, for all the COPCs except Aroclor 1248.

11.3.5.3 Goose Island Slough

No unique COPCs were selected for Goose Island Slough (Table 11-3). All COPCs with bioaccumulation potential that were selected for Goose Island sediments were already included among the Forebay sediment COPCs. No other COPCs were selected for sediment since direct contact with sediments is not likely. All COPCs identified for crayfish tissue from Goose Island Slough were already included as COPCs for crayfish tissue for the rest of the Forebay. All smallmouth bass collected from this area were included in the 95% UCL calculations for with the Forebay bass samples.

In summary, COPCs that are unique to Goose Island Slough were not identified.

11.4 Recommendations

Following the completion of the problem formulation, the recommendations for each AOPC and OU are presented in this section.

11.4.1 Upland OU

The Upland OU COPCs recommended for Risk Management are summarized in Tables 11-1 and 11-2.

Landfill AOPC

One of two options is recommended for the Landfill AOPC.

1. Perform a Baseline HHRA since no medium could be eliminated during the problem formulation. All the receptors except Excavation Worker are also retained.

2. Evaluate targeted removal or response actions to achieve acceptable residual concentrations of COPCs. Areas for such consideration include the Gully Test Pit and the Mercury Vapor Lamp Test Pit.

Sandblast Area AOPC

One of two options is recommended for the Sandblast Area AOPC.

1. Perform a Baseline HHRA since no medium could be eliminated during the problem formulation. All the receptors except Excavation Worker are also retained.

2. Evaluate targeted removal or response action for soil, groundwater, and soil gas to achieve acceptable residual concentrations of COPCs.

Pistol Range AOPC

Due to the lack of COPCs for the exposure pathways identified in the CEM, the Pistol Range AOPC is not considered to pose a threat to human health. No additional evaluation of this AOPC is warranted and a baseline human health risk assessment (BHHRA) is not necessary.

Bulb Slope AOPC

Given the absence of COPCs, the limited number of receptors, exposure pathways and exposure media for the Bulb Slope AOPC, this area is not considered to pose a threat to human receptors. No additional evaluation is warranted and a BHHRA is not necessary.

11.4.2 River OU

The River OU COPCs recommended for Risk Management are summarized in Table 11-3.

Forebay Area

Further evaluation is recommended for the Forebay, which may include the monitoring of PCB concentrations in Forebay tissue.

Mouth of Eagle Creek

Similar to the Forebay, further risk evaluation is recommended for sediments at the mouth of Eagle Creek, which may include the monitoring of PCB concentrations in Forebay tissue.

Goose Island Slough

No further evaluation of Goose Island media is necessary for the HHRA process because all COPCs identified for Goose Island were already identified for the Forebay.

12.0 ECOLOGICAL RISK ASSESSMENT

This section presents the methodology and findings of the Level I/Level II ERA that was performed for the Upland and River OUs (Figure 1-3) in support of the RI. The ERA process is similar for the River and Upland OUs, as described in the RI/FS MP (URS 2007a).

The overall purpose of the ERAs for the Upland and River OUs is to determine whether site-related chemicals are present at concentrations that could have adverse effects on the environment and to guide future decision-making for risk management, if warranted. Due to the very different site conditions and habitat types found within these two OUs, the ERAs also answer questions specific to each OU that will assist with risk management decisions. For example, in the River OU, PCBs in sediments and tissues have been the main focus of site characterization and investigation efforts over the last several years. Although other site-related chemicals are likely present within the Forebay area of the River OU and will be evaluated, the exposure scenarios associated with this aquatic environment create an emphasis on the importance of assessing bioaccumulation and ingestion pathways. In contrast, based on historical operations in the Upland OU and associated exposure pathways, bioaccumulation is also important, but not due to the presence of PCBs (other bioaccumulative COIs are present). In addition, the potential for transport of Upland media (soil and groundwater) to the River OU was an important evaluation conducted in the ERA for the Upland OU.

The primary objectives for the ERAs for the Upland and River OUs are as follows:

Upland

- Are site-related chemicals in soil of each AOPC at levels potentially harmful to terrestrial biota?
- Is exposure to all AOPCs combined a potential concern for wide-ranging terrestrial receptors?
- Are site-related chemicals in upland groundwater entering the adjacent River OU at levels of potential concern for benthic and aquatic biota?
- Is there a potential for site-related chemicals in upland soils to erode into the River OU at levels of potential concern for benthic and aquatic biota?

River

- Are site-related chemicals in Forebay sediment and tissue at levels potentially harmful to aquatic biota?
- What is the upstream contribution to chemicals detected in Forebay media at levels of potential concern for aquatic biota?
- Do site conditions support the beneficial uses of the Columbia River in this segment including the protection of anadromous and resident fish species and wildlife preservation?

If the findings of the ERAs indicate that further investigation or risk management may be necessary to address potential concerns in either OU, then recommendations will be made as to the scope and focus of these efforts.

The following section summarizes the framework that was used to conduct the ERAs and the scope of the current risk assessments.

12.1 Overview of Level I and Level II Screening Assessments

This section describes the tiered framework that was followed for the ERA, including a summary of the evaluation that was performed during each phase of the assessment.

12.1.1 Regulatory Framework

To achieve the objectives mentioned above, the steps that were used to conduct the Level I Scoping and Level II Screening ERAs concur with federal and state guidance documents (USEPA 1997a,b, 1998, and 2005a; DEQ 2001 and 2007). Since DEQ is reviewing the RI/ FS, DEQ guidance was followed regarding the nature of the risk assessment process and the format and presentation of results. DEQ risk assessment protocols can be found in OAR Section 340-122-0084.

The guidance documents used in the performance of the ERA include:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA 1997a)
- EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund (USEPA 1997b)
- Guidelines for Ecological Risk Assessment (USEPA 1998)
- Guidance for Developing Ecological Soil Screening Levels, Revised Draft (USEPA 2005a)
- Ecological Soil Screening Levels, Interim Final (USEPA 2005-2008)
- Guidance for Ecological Risk Assessment, Final (DEQ 2001)
- Comments on Revised Draft Level II Ecological Risk Assessment and Baseline Human Health Risk Assessment, Bonneville Lock and Dam Project (DEQ 2004)
- Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites (DEQ 1998a)
- Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment, Final (DEQ 2007)
- Data Usability Guidelines for Risk Assessment (USEPA 1992)
- Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites (USEPA 2002a)
- Calculating UCLs for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002b)

As discussed in Appendix C of the RI/FS MP (URS 2007a), a tiered framework was implemented in accordance with USEPA and DEQ guidance (USEPA 1997a,b; DEQ 2001) and consists of the following steps: Level 1 Scoping, Level II Screening, Level III Baseline, and

Level IV Field Baseline. A brief description of the first three steps is provided below. The first two steps were conducted for both the River and Upland OU ERAs:

Level I Scoping Assessment

- Provide a conservative qualitative determination of whether ecological receptors and exposure pathways are present or potentially present at a site or in the vicinity.
- Identify sites that are obviously devoid of ecological important receptors or habitats and where exposure pathways are obviously incomplete.
- Identify sites and COIs that warrant additional risk-based evaluation.

Level II Screening Assessment

- Construct a site description based on information from site visits and/or surveys, the existing literature, any prior PAs, and site history (including past and present uses).
- Identify site-specific ecologically important receptors, and the relevant and complete exposure pathways between each source medium of concern and these receptors. Identify CPECs from among the COIs associated with the site.
- Discuss how the physicochemical and toxicological properties of each CPEC may influence exposure pathways and adverse effects.
- Define ecologically appropriate assessment endpoints.
- Establish potential links between CPECs and responses in site-specific receptors by means of a preliminary CEM.
- Make an initial evaluation of the potential for site-related risk.

Level III Baseline Assessment

- Determine whether a site, if left unremediated, would pose unacceptable current or reasonably likely future risks to endpoint species.
- Provide the basis for determining if remediation is needed.
- Provide information for developing remedial alternatives.
- Identify contaminants of ecological concern (CECs) to be addressed further.

At the end of each tier of the evaluation, stakeholders have an opportunity to discuss the best path forward for the project, whether it be supporting a decision for NFA, deciding to take a remedial action, or continuing to the next phase of the ERA process. In order to ensure all stakeholders are comfortable with the results of the first quantitative step of the ERA process in which CPECs are identified from the initial list of COIs, this combined Level I Scoping/Level II Screening ERA is being submitted for review prior to moving forward to Level III BERA).

12.1.2 Scope of ERA

Based on the extensive site characterization that has been performed in the River and Upland OUs and the biological information that has been documented near the island, the findings of the Level I Scoping ERAs are predictable (i.e., complete exposure pathways exist that should be

evaluated further in a quantitative manner). This is the reasoning behind the combined Level I Scoping/Level II Screening ERA. At the completion of the Level II Screening, the utility of a Level III BERA, which would involve a more rigorous evaluation of the site data, is considered and recommendations are made accordingly.

12.1.3 Data Management for ERA

In Sections 5.0 and 6.0, the datasets evaluated in the Level II Screening Assessments for the Upland and River OUs are described, including the methods used to handle data qualifiers and non-detect sample results. The approach used to calculate PCB totals from Aroclor and congener data, as well as the approach used to calculate PAH totals, are also discussed in Section 5.1. Finally, an evaluation of the data usability for the ERA is provided in Section 7.4, whereby MDLs and MRLs for non-detect samples and MRLs for J-flagged data are compared to SLVs protective of ecological receptors to assess the quality of the data. A more detailed description of MDLs for non-detect samples in exceedance of ecological SLVs is presented in the uncertainty assessment (Appendix O).

12.2 Level I Scoping Assessment For Upland OU

The tasks required to complete the Level I Scoping Assessment are as follows:

- Review existing data
- Perform initial site visit
- Identify COIs
- Evaluate receptor-pathway interactions

In an effort to streamline the risk assessment process, the Level I Scoping Assessment (URS 2002d) originally performed for the Landfill was expanded to the other three AOPCs. The close proximity of the Upland AOPCs to each other and the similarities in habitats and organisms present support this approach. To fulfill the requirements listed above, the ecological setting, site features (topography, structures), nature and extent of all known chemical releases, current and future uses of land and water, and any unique site-specific characteristics described in previous sections were carefully considered.

12.2.1 Identification of COIs and CPECS

COIs are defined as chemicals that are present or may be present at a site that have not been screened against any criteria (DEQ 2001). For the purposes of an ERA, COIs may be further evaluated on the basis of detection frequency, comparison with background levels, and risk-based screening. COIs that fail the evaluation, or those COIs without screening levels, are retained as CPECs and may be recommended for risk management, while COIs that pass the evaluation are dropped from further consideration.

The following steps comprise DEQ's general screening criteria used to identify CPECs. COIs for which any of these criteria are met need not be retained as CPECs (DEQ 2001):

4. COIs detected at less than a 5% detection frequency, assuming adequate nature and extent delineation and acceptable reporting limits (i.e., below benchmarks protective of ecological receptors);

5. Inorganic COIs present at concentrations below naturally occurring levels that are either site-specific or derived from regional concentrations;
6. COIs that are below toxicity-based criteria established for ecological receptors based on exposure to individual COIs, as well as cumulative exposure to all COIs and all possible media available to a given receptor.

Although these criteria may be met, a COI may still be retained as a CPEC under the following two circumstances:

1. COIs that are detected at least once and are bioaccumulative require further investigation for their potential to impact upper-trophic-level ecological receptors through the dietary pathway (if a bioaccumulation-based benchmark is not available);
2. COIs that lack toxicity-based criteria (e.g., SLVs) require further consideration, such as a qualitative assessment of risk.

All CPECs identified on the basis of exceedances of SLVs or concerns related to the bioaccumulation pathway for CPECs exceeding dietary based SLVs or lacking dietary based SLVs are retained for further evaluation or remediation. In the uncertainty assessment (Appendix O), COIs that were eliminated based on detection frequency were evaluated to ensure these COIs do not pose an unacceptable risk. Groundwater and soil of the Landfill and Sandblast Area AOPCs were the only areas where elimination of COIs based on frequency of detection occurred.

In Sections 5 and 6, the historical and recent site investigations are described in detail, and the COIs in Upland media of the four AOPCs are identified. Based on the presence of potentially complete exposure pathways and associated analytical data, COIs in the Upland OU were identified for the following media:

- Soil, groundwater, seep, and co-located surface water of the Landfill AOPC
- Soil and groundwater of the Sandblast Area AOPC
- Soil and lagoon sediment of the Pistol Range AOPC
- Soil of the Bulb Slope AOPC

To summarize, the categories of COIs that were detected in analytical data include metals (including butyltins), pesticides, herbicides, PCBs, TPH, PAHs, other SVOCs, and VOCs. Of these COIs, a subset is considered to be bioaccumulative in terrestrial soils, or aquatic environments (for the groundwater to surface discharge scenario), as presented in Section 7.3 and Table J-6. The screening tables described in Section 12.3.4 and presented in Appendix N include the bioaccumulative COIs detected at each individual AOPC.

12.2.2 Ecological Exposure Pathways

All Upland AOPCs on Bradford Island are similar with regard to land and water uses, habitats present, potentially exposed receptors, and exposure routes, but the sources of contamination and COIs vary from one AOPC to another. The affected Upland media include surface soils (0 to 1 foot bgs), subsurface soils (1 to 3 feet bgs), and groundwater. Soils are the source for uptake of bioaccumulative chemicals by terrestrial plants, soil invertebrates, and small mammals, which are consumed by upper trophic level receptors.

The following Upland-related exposure pathways are identified as potentially complete for the Upland OU, and these pathways were more thoroughly investigated to identify those that warrant a quantitative evaluation in the Level II Screening Assessment (Section 12.3.2.1):

- Root uptake of contaminants in surface and subsurface soil by terrestrial plants
- Direct contact (ingestion of and dermal contact) with surface and subsurface soil by soil invertebrates
- Dermal contact with and incidental ingestion of surface and subsurface soil by birds and mammals (although in the absence of burrowing birds at the site, ingestion of subsurface soils by birds is questionable)
- Inhalation of soil-related particulates and VOCs originating from shallow and subsurface soils by burrowing animals
- Ingestion of terrestrial dietary components (e.g., plants, soil invertebrates, and small mammals) by upper trophic level receptors
- Incidental ingestion of and direct contact with potentially contaminated sediment or surface water by aquatic life and aquatic-dependent wildlife, including aquatic prey consumption by upper trophic levels (e.g., fish and wildlife)

Rooting depths for plants and burrowing depths for invertebrates and mammals were assumed to occur within the upper 3 feet of soil, and it will be assumed that all terrestrial receptors are exposed to soils from this depth interval. This is a conservative assumption for birds, which typically do not burrow and forage on the ground surface, and mammals that burrow are more likely to consume organisms that are exposed to soils below the surface. The Landfill and Sandblast Area AOPCs were evaluated for both the surface (0-1 foot bgs) and shallow (0 to 3 feet bgs) intervals. For the Pistol Range and Bulb Slope AOPCs, only surface soil-related pathways were evaluated (0 to 1.5 feet bgs and 0 to 1 foot bgs, respectively).

As noted in Section 3.5.1.3, a review of historical activities and the source of contamination at the Pistol Range AOPC (bullets and casings from firing practice) are consistent only with surface impacts; therefore, deeper samples do not need to be evaluated for this AOPC. Since the Bulb Slope AOPC only has a thin layer of soil underlain by a bedrock base, there are no soils deeper than 1 ft bgs in this area and the existing surface soil data are sufficient to evaluate risk.

Groundwater is only a medium of concern if it has the potential to enter a surface water body; otherwise, exposure to groundwater is an incomplete pathway for most terrestrial receptors with the possible exception of plants. Groundwater levels in the Upland OU are deeper than 3 feet bgs, i.e., root depth zone for terrestrial plants. Therefore, exposure of plants to groundwater is not expected to occur. The potential for groundwater discharge to surface water and ultimate exposure by aquatic biota is discussed in the following section.

Sections 4.3 and 10.1 describe the potential Upland OU to River OU transport pathways, and the key physical migration pathways may be summarized as followed:

- Slope failure
- Mobilization of soils via erosion
- Groundwater seepage

The exposure pathways that are complete at each AOPC and their associated receptors were quantitatively evaluated in the Level II Screening Assessment.

12.3 Level II Screening Assessment for Upland

This section describes the methodology and findings of Level II Screening Assessment for the Upland OU. The comprehensive investigation of the nature and extent delineation is provided in Section 9.0. In Section 9.1.1, the first two steps of the CPEC selection process (evaluation of detection frequency and comparison to background levels for inorganics) were performed for all media associated with each AOPC (Tables 9-1 through 9-6). In addition, the lowest of the SLVs for human and ecological receptors was used for this initial screening to identify preliminary COPCs to assist in evaluating the nature and extent of contamination.

12.3.1 Receptors of Interest

A simplified model of the terrestrial food web for the Upland OU is presented on Figure 12-1. Discussion regarding the selection of avian and mammalian receptors of interest (or "target receptors") occurred in several meetings during 2005 and early 2006 with the TAG for Bradford Island and in RTC received from DEQ (2004). The following terrestrial receptors of interest were selected in the RI/FS MP (URS 2007a):

- Terrestrial plants
- Soil invertebrates
- American kestrel (*Falco sparverius*)
- American robin (*Turdus migratorius*)
- Canada goose (*Branta canadensis*)
- Vagrant shrew (*Sorex vagrans)*

In addition, the American mink (*Mustela vison*) was selected as a large mammal predator to address exposure through consumption of chemically-impacted rodents. In the Level II Screening Assessment, these organisms are evaluated as receptor groups (plants, invertebrates, terrestrial birds and mammals) through a comparison to generic SLVs for each group. During a Level III BERA, the specific receptors listed above, which represent the feeding guilds present in the Upland OU, would be assessed for exposure and risk.

12.3.2 Exposure Assessment

Exposure assessment is the process of estimating the magnitude, frequency, and duration of site-specific exposure concentrations of chemicals to a receptor. To assess whether COI concentrations at the site have the potential to cause adverse effects in the selected ecological receptors, it is first necessary to develop reasonable estimates of the concentrations to which the receptors might be exposed.

12.3.2.1 Conceptual Exposure Model for Ecological Receptors

CEMs for ecological receptors that may be present at each Upland AOPC are presented as Figures 12-2 through 12-5. An exposure pathway is considered complete when the following components are present:

- A source of COIs (e.g., waste material in a landfill)
- A release mechanism (e.g., spills and releases)
- An exposure medium (e.g., surface soil)
- A receptor (e.g., plant community, small mammals)
- An exposure route (e.g., route uptake, ingestion)

When any of these elements is missing, the pathway is considered incomplete. By definition, no risk occurs where no complete pathway exists.

In general, all Upland AOPCs on Bradford Island are similar with regard to land and water uses, habitats present, potentially exposed receptors, and exposure routes, although the sources of contamination and COIs vary from one AOPC to another. Most of the AOPCs in the Upland OU generally provide good habitat for animals that occur in the Lower Columbia River watershed, i.e., the Landfill AOPC, which is managed as wildlife habitat (primarily for Canada geese) and the Pistol Range AOPC. The Sandblast Area AOPC is more highly disturbed and is still partially occupied by the current HMSA, paved roads and areas, and an equipment lay-down area (Section 3.1.5).

The CEM for each AOPC illustrates the current understanding of potential contamination sources, receptors of interest, and routes of exposure. The ecological exposure pathways discussed in the Level I Scoping Assessment (Section 12.2.2) are shown on the CEM figures, and the ones designated as potentially complete and significant were included in the quantitative analysis:

- Root uptake of contaminants potentially present in surface and subsurface soil by terrestrial plants
- Direct contact with contaminants potentially present in surface and subsurface soil by soil invertebrates
- Incidental ingestion of surface and subsurface soil by birds and mammals (although in the absence of burrowing birds at the site, ingestion of subsurface soils by birds is questionable)
- Ingestion of terrestrial dietary components (e.g., plants, soil invertebrates, and small mammals) by birds and mammals
- Incidental ingestion of and direct contact with COIs in Upland groundwater by aquatic biota
- Consumption of aquatic prey that has been exposed to bioaccumulative COIs in Upland groundwater or erodible and mass wasting soils by upper trophic levels (e.g., fish and piscivorous wildlife)
- Direct contact with contaminants potentially present in the Pistol Range lagoon sediments by sediment-dwelling invertebrates; these upland contaminants may have been impacted by historically erodible soils that were transported to the lagoon

- Direct contact with contaminants potentially present in erodible and mass wasting soils that have or may have been transported to the River OU by sediment-dwelling invertebrates

All of these pathways are potentially complete for the Landfill and Sandblast Area AOPCs and were quantatively evaluated. For the Pistol Range and Bulb Slope AOPCs, only surface soil-related pathways were evaluated (0 to 1.5 feet bgs and 0 to 1 foot bgs, respectively). Groundwater-related pathways were also evaluated for the Pistol Range AOPC; there are no groundwater-related pathways from the Bulb Slope AOPC. Finally, sediment data collected from the lagoon adjacent to the Pistol Range AOPC were evaluated for potential exposure by benthic organisms and fish and wildlife.

12.3.2.2 Assessment Endpoints

Assessment endpoints are explicit expressions of the actual environmental value to be protected, and may be perceived as an environmental characteristic. If these endpoints are found to be significantly affected they can trigger further action. The following assessment endpoints were selected for the ecological receptors addressed in the Upland OU:

- Protection of the terrestrial plant community and soil-dwelling invertebrate populations that may be exposed to COIs in soil to maintain species diversity, abundance, and nutrient cycling
- Protection of herbivorous small birds (Trophic Level 1), such as Canada geese, with no unacceptable effects on reproduction, growth, or development at the population level due to COIs in soil and terrestrial plants
- Protection of invertivorous birds (Trophic Level 2), such as the American robin, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates
- Protection of carnivorous small mammals (Trophic Level 2-3), such as the vagrant shrew, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates
- Protection of top-level predatory birds (Trophic Level 3-4), such as the American kestrel, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and small mammals
- Protection of predatory mammals (Trophic Level 3-4), such as the American mink, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and small mammals
- Protection of aquatic biota (invertebrates, fish, and wildlife) that may be exposed to COIs in groundwater or erodible soils from the Upland OU that have been transported to the River OU

The disturbed nature of some of the Upland AOPCs, e.g., Sandblast Area, precludes high quality habitat and species diversity. Furthermore, no state- or federally listed threatened and endangered terrestrial species are known to occur on the island, with the exception of the bald eagle (which is evaluated for the River OU), and site-related effects on an individual basis are only of concern for this receptor. The methodology for evaluating risks to both threatened and endangered and

nonthreatened and endangered species was included in the assessment. Recommendations in support of risk-management decisions were primarily based on risks to non-threatened and endangered terrestrial species.

According to Section 3.5 of the Level I Scoping Assessment that was performed for the Landfill (URS 2002d), which included a thorough biological characterization of the Landfill and all habitats on the island, "large mammalian predators do not occur on the island." The only mammals on the island that are described in the Scoping Assessment are small mammals (rodents) and feral cats: "Although the island harbors small mammals, feral cats, Canadian geese, and other bird species, the minimal amount of available habitat (~12 acres) makes it unsuitable for supporting viable populations of wildlife species with larger home ranges" (URS 2002d). For this reason, large mammals were not included in the assessment endpoints described in the approved RI/FS MP (URS 2007a). However, because mink are present in the area and could feasibly access the island and forage there, exposure by predatory mammals that consume rodents was considered in the assessment endpoints.

12.3.2.3 Estimation of Exposure Point Concentrations

The EPC is the concentration of a chemical in an environmental medium at the point of contact for the receptor (e.g., the concentration of a chemical in soil at a sampling location that could serve as habitat for the receptor). For terrestrial plants and soil invertebrates, the EPC is estimated as a function of the COI concentration measured in soil. For higher trophic level receptors, the exposure dose may be estimated as a function of the COI concentration in relevant environmental media and several other parameters related to biological transfer through the food web and the manner in which receptors use the site (e.g., dietary composition, feeding strategy, food ingestion rate, length of time a receptor is expected to forage/nest at the site based on their home range size and seasonal behavior).

Soil EPCs were developed for surface soils (0 to 1 foot bgs) and shallow soil (surface and subsurface soils; 0 to 3 feet bgs) for all terrestrial receptors. More refined exposure depths may be considered for nonburrowing animals for COIs that fail the Level II Screening Assessment. Additionally EPCs were developed for groundwater, seep water, surface water, and lagoon sediment for semi-aquatic and/or aquatic receptors.

Plants and Invertebrates - EPCs in soil were estimated for receptors with limited or no mobility (i.e., plants and invertebrates) using the maximum detected concentration in soil and sediment. Use of the maximum concentration of each COI is a conservative approach that serves to protect stationary receptors that could conceivably be exposed to the maximum concentration throughout their entire life span. In addition, for many CPECs, point by point evaluations were performed through spatial mapping to understand the spatial distributions of SLV exceedances for these receptor groups.

Birds and Mammals - For food web-based receptors such as birds and mammals, the EPC was based on the 95% UCL on the mean concentration in soil and was estimated using statistical methods recommended by USEPA (generated from the USEPA's ProUCL software [USEPA 2011]). The lower of the 95% UCL and maximum detected concentration in soil was used as the EPC for birds and mammals. This value provides an estimate of the representative concentration more relevant to terrestrial wildlife receptors that generally are mobile and not continuously

exposed to site-related COIs in one geographic location. Soil EPCs were directly compared to DEQ's SLVs protective of birds and mammals or equivalent soil benchmarks in the screening (Sections 12.3.4.1).

Aquatic Biota of River OU - EPCs in potentially mass wasting or erodible soils and groundwater evaluated for aquatic biota, with the exception of benthic invertebrates, are represented by the lower of the 95% UCL and maximum detected concentration, as described above for birds and mammals. Since some types of benthic invertebrates in the River OU have limited mobility (i.e., clams), the maximum detected concentration in potentially mass wasting or erodible soils was used as the EPC for this receptor group. The evaluation of potentially mass wasting and erodible soils is presented in the uncertainty assessment (Appendix O).

12.3.3 Effects Analysis

The identification of toxic effects and chronic toxicity thresholds resulting from exposure to COIs comprises the effects assessment phase of the Screening Assessment. A qualitative and quantitative description of the relationships between COI concentrations or doses and the nature of possible effects elicited in exposed receptors, populations, or ecological communities is discussed in this section. The goal of this effects assessment is to identify risk-based screening levels, or SLVs, that are most relevant to the receptors and assessment endpoints identified for the Upland OU. SLVs are expressed as concentrations in media (e.g., mg/kg of soil).

Although "screening levels" are typically associated with exposure via direct contact, and are also commonly referred to as direct toxicity benchmarks, there are sources of generic media-based screening levels that address both direct contact and dietary exposure for birds and mammals. SLVs for birds and mammals are derived from diet-based toxicity reference values (TRVs) that are expressed as a daily dose normalized to body weight (mg of chemical/kg of body weight/day).

12.3.3.1 Measurement Endpoints

Measurement endpoints are measurable changes in an attribute of an assessment endpoint that allow an evaluation of whether or not the ecological resource is being sufficiently protected. Measurement endpoints are typically characterized in two parts: measures of exposure and measures of effect. Measures of exposure are measurable characteristics or attributes of an assessment endpoint or an acceptable surrogate (e.g., COI concentrations in soil or tissue). Measures of effect are measurable responses in the assessment endpoint or its surrogate associated with lowest adverse effects or acceptable no-effect thresholds (e.g., ecologically protective screening values for soil and tissue). The measures of exposure and measures of effect proposed for the assessment endpoints were provided in Table C-1 of the RI/FS MP (URS 2007a).

Measurement endpoints for the Upland ERA include measured EPCs in soil and groundwater (and seep/co-located surface water for the Landfill AOPC), modeled concentrations of CPECs in terrestrial organism tissues, and field observations (e.g., areas of distressed vegetation or bare soil, visible sandblast grit, or lack thereof).

12.3.3.2 Direct Toxicity and Bioaccumulation SLVs

The EPCs derived for soils, sediment, and water were compared to the SLVs protective of the individual receptor groups of interest (e.g., terrestrial plants, soil-dwelling invertebrates,

terrestrial wildlife, and aquatic biota). The primary literature sources of SLVs protective of ecological receptors that were used in the Level II Screening Assessment were presented in Section 7.3.1 and Appendix J.

12.3.3.3 Identification of Chemicals of Potential Ecological Concern

The first two steps of the CPEC identification process presented in Section 12.2.1 (i.e., evaluation detection frequency and comparison to Reference Area concentrations for inorganics) were performed for each AOPC dataset and the combined AOPCs dataset in Section 9.1.1. In the first step, Upland OU COIs that were detected in ≤ 5% of samples per media and AOPC were not retained as CPECs, as long as there were at least 20 samples collected. Multiple COIs were eliminated as potential CPECs in this first step of the evaluation. In the uncertainty assessment (Appendix O), COIs that were eliminated based on detection frequency were evaluated to ensure these COIs do not pose an unacceptable risk. Groundwater and soil of the Landfill and Sandblast Area AOPCs were the only areas where elimination of COIs based on frequency of detection occurred.

For the second step, a statistical comparison of two independent datasets was performed between the Reference Area surface soil data and the Upland OU soil data (for each depth interval; 0-1 and 0-3 ft bgs) within each AOPC. In addition, the comparison to Reference Area soils was performed for the combined data sets (including all four Upland AOPCs) for each depth interval. The objective of the statistical analysis was to assess whether the mean inorganic COI concentrations in soil within each AOPC, as well as the mean soil COI concentrations for all four AOPCs combined, were significantly higher than the mean Reference Area concentrations. This approach is commonly known as a population-to-population comparison. The results of this statistical comparison are presented in detail in Section 8.2.1 and Appendix L and summarized in Table 8-1.

There are insufficient groundwater data to perform statistical comparisons between site and reference area data. Therefore the groundwater and seep water data were evaluated by comparing the range of COI concentrations observed in groundwater samples from monitoring wells and in seep samples with the range of concentrations observed in the Reference Area monitoring well (MW-10). The results are summarized in Appendix L, Table L-3 and Table 8-2

The COIs detected above a 5% detection frequency and inorganic COIs with concentrations higher than Reference Area levels (see Tables 9-1 through 9-7), were retained for the third step of the CPEC identification process, (i.e., toxicity-based screening). The approach used for this evaluation is described in the following section.

In addition to the first three quantitative steps of the process, the potential for bioaccumulation and the availability of SLVs are two additional qualitative elements that were evaluated in the identification of CPECs.

12.3.3.3.1 Toxicity Ratios for Individual COIs within a Given Medium

Toxicity ratios were developed based on the following equations and logic:

$$T_{ij} = \frac{C_{ij}}{SLV_{ij}}$$

COIs with T_{ij} > Q

were retained as CPECs.

where:

T_{ij} = Toxicity ratio for COI *i* in medium *j* (unitless)

C_{ij} = Environmental concentration of COI *i* in medium *j* (mg COI per kg environmental medium);

SLV_{ij} = Screening level value for COI *i* in medium *j* (mg COI per kg environmental medium)

Q = Receptor designator that dictates the level of protection appropriate for a certain site (unitless)

If T_{ij} for a specific COI is greater than the receptor designator (Q) appropriate for the site, then further investigation of the COI is warranted and it was retained as a CPEC. As defined by DEQ (2001), Q is equal to 1.0 for listed threatened and endangered species and Q equals 5.0 for nonthreatened and endangered species. However, for this project, CPECs were identified when Q is equal to 1.0 for terrestrial plants, soil invertebrates, and birds, and Q is equal to 5.0 for mammals. Although no threatened and endangered plant or soil invertebrate species are potentially present, a Q of 1.0 was applied for these receptor groups at request of DEQ due to basis of certain SLVs (e.g., USEPA's Eco-SSLs, 2005 - 2008). Nonetheless, consideration of a Q equal to 5.0 was also considered during the risk interpretation phase. Likewise, selection of CPECs at the Q equal to 1.0 level to account for the bald eagle, and possible transient juvenile spotted owls is appropriate, but these special-status species are not likely to forage at the 1.36 acre Landfill AOPC. For this reason, the Q equal to 5.0 level for birds in the Upland OU is also considered in the risk interpretation. For all aquatic (and benthic) organisms, the Q is equal to 1.0 threshold was used (DEQ 2001).

12.3.3.3.2 Evaluation of Multiple COIs Simultaneously within a Given Medium

To assess the potential for cumulative effects attributed to multiple COIs within soil, all COIs present in a given medium was collectively compared to SLVs. Based on the toxicity ratios estimated from the equation above, the incremental effects from each COI was identified from the approach expressed in the following equation:

$$\text{COIs with } \frac{T_{ij}}{T_j} \geq \frac{1}{N_{ij}} \times Q$$

was retained as CPECs.

where :

T_{ij} = Toxicity ratio for COI *i* in medium *j* (unitless)

T_j = Summation of toxicity ratios for *i* COIs in medium *j* (unitless)

N_{ij} = Total number of *i* COIs in medium *j* for which an SLV is available (unitless)

Q = Receptor designator that dictates the level of protection appropriate for a certain site

(unitless)

If the toxicity ratio for a specific COI is a high contributor to the total risk for a given medium, represented by the summation of all toxicity ratios (T_j), then further investigation of the COI is warranted and it was retained as a CPEC. This approach allows evaluation of the incremental risks associated with simultaneous exposure to multiple COIs. As stated previously (Section 12.3.3.3.1), Q is equal to 1.0 for terrestrial plants, soil invertebrates, birds, and aquatic and benthic organisms, and Q equals 5.0 for mammals.

12.3.4 Risk Characterization

Risk characterization is the process of integrating the previous elements of the risk assessment into quantitative or semiquantitative estimates of risk. Risk characterization consists of risk estimation and uncertainty assessment. Risk estimation or the quantification of risk is then used as an integral component in remedial decision making and selection of potential remedies or actions. Uncertainty assessment describes the level of confidence in the risk estimation.

12.3.4.1 Results of Screening for Each AOPC

The toxicity screening for COIs in soil at all four AOPCs, groundwater at all AOPCs except the Bulb Slope AOPC, seep and surface water for the Landfill AOPC, and lagoon sediment for the Pistol Range AOPC involved a comparison of appropriate EPCs to soil, water, and sediment SLVs protective of the receptor groups evaluated in this Level II Screening Assessment. The potential for ecological risk to occur was evaluated based on exposure to individual COIs within a specific medium and from exposure to multiple COIs simultaneously within a given medium.

Toxicity ratios were estimated for each COI, and COIs were retained as CPECs as described above (Section 12.3.3.3). COIs were also retained as CPECs if there are no SLVs available (referred to as "Yes – No SLV" in the risk tables) or if the COI is bioaccumulative but lack of a dietary-based SLV and precluded appropriate evaluation of this pathway (referred to as "Yes-Bio" in the risk tables). The implications of not performing a quantitative evaluation for CPECs without SLVs and bioaccumulative CPECs without dietary-based SLVs are explained in Section 7.4 and in the uncertainty assessment (Appendix O).

The following sections present the results of the screening process for each AOPC for all receptors and all four AOPCs combined for birds and mammals. For soils, the screening results for the 0 to 1 foot-depth interval and 0 to 3 feet-depth interval are shown on the same tables. In the following sections, if individual benzofluoranthenes (e.g., benzo(b)fluoranthene) were retained as a CPEC, then the total benzofluoranthenes were not included in the CPEC counts. For soil invertebrates and mammals, individual LPAHs and HPAHs were screened by their respective total PAH SLVs in order to determine which individual PAHs drive risk.

The data from the surface soil samples (0-1 ft bgs) collected within the potentially erodible/mass wasting areas identified within the Upland OU were utilized for evaluation of the overland transport pathway. The results of the evaluation to address overland transport through mass wasting and soil erosion into the River OU is provided in Appendix O (Tables O.3-5 through O.3-11).

12.3.4.1.1 Landfill AOPC

Tables N-1 through N-5 of Appendix N present the results of the screening for individual COIs evaluated for terrestrial plants, soil invertebrates, birds, mammals, and aquatic organisms. Tables

N-6 through N-10 provide the results of the toxicity-based screening analysis that involved an evaluation of the cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

Terrestrial Plants - In surface and shallow soil, arsenic (shallow soil only), lead, mercury, zinc, LPAHs , and HPAHs have toxicity ratios greater than 1.0 (Table N-1) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the plant community at the Landfill AOPC.

Lead (shallow soil only), mercury, and nine HPAHs contribute to a cumulative risk greater than 1.0 (Table N-6). All of these HPAHs were already identified as CPECs based on the individual COI screening evaluation.

Soil Invertebrates - Two metals (mercury and zinc), ethylbenzene, carbazole, and Total HPAHs have toxicity ratios greater than 1.0 (Table N-2) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the soil invertebrate community at the Landfill AOPC. To be consistent with the Ecological Soil Screening Levels (EcoSSL) guidance, total HPAHs (and total LPAHs) were screened against the corresponding SLVs, and the individual HPAHs were evaluated from the perspective of their contribution to the toxicity ratio for total HPAHs.

These same three CPECs contribute to a cumulative risk greater than 1.0 (Table N-7).

Birds - Five metals (antimony, cadmium, lead, mercury and zinc), two herbicides, and B2EHP have toxicity ratios greater than 1.0 (Table N-3) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual birds at the Landfill AOPC. Of these eight CPECs, antimony, lead, mercury (and zinc at 0 to 3 foot bgs only) and MCPP (an herbicide) have toxicity ratios greater than 5.0. All PAHs except naphthalene, as well as eight other bioaccumulative COIs, were retained as CPECs due to the lack of SLVs that address the dietary pathway.

Antimony (shallow soils only), lead, mercury, and MCPP contribute to a cumulative risk greater than 1.0 (Table N-8). All of these COIs were already identified as CPECs based on the individual COI screening evaluation.

Mammals - In surface and shallow soil, antimony, lead, mercury, zinc (shallow soil only), two herbicides, dibenzofuran, and HPAHs have toxicity ratios greater than 5.0 (Table N-4) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in mammal populations at the Landfill AOPC. To be consistent with the EcoSSL guidance, total HPAHs (and total LPAHs) were screened against the corresponding SLVs, and the individual HPAHs were evaluated from the perspective of their contribution to the toxicity ratio for total HPAHs. There are eight bioaccumulative COIs that were retained as CPECs due to the lack of SLVs that address the dietary pathway. Even though three individual HPAHs have toxicity ratios less than 5.0, all HPAHs were retained as CPECs for mammals because the total HPAH toxicity ratio is above 5.0 and all are potentially bioaccumulative.

When evaluating cumulative risk, no additional COIs contribute to a risk greater than 5.0 for mammals (Table N-9).

Aquatic Organisms and Aquatic-Dependent Wildlife - Four metals (barium, iron, manganese and zinc) and B2EHP in groundwater have toxicity ratios greater than 1.0 (Table N-5) and require further investigation in the risk interpretation section to assess their potential to elicit

adverse effects in individual aquatic organisms or wildlife that could be exposed to surface water that has been impacted by COIs in groundwater of the Landfill. Barium, iron, manganese, and zinc also have toxicity ratios greater than 1.0 for seep water (Table N-5). No COIs for surface water samples that are co-located with the seep samples have toxicity ratios greater than 1.0. There are 11 bioaccumulative COIs in groundwater, as well as two in seep water and two in surface water, that were retained as CPECs due to the lack of SLVs that address the dietary pathway (Table N-5).

Barium, iron, and manganese contribute to a cumulative risk greater than 1.0 for groundwater, and barium and manganese also contribute to a cumulative risk greater than 1.0 for seep water (Table N-10). No individual COI contributes to a cumulative risk greater than 1.0 for co-located surface water. All of these COIs were already identified as CPECs based on the individual COI screening evaluation.

12.3.4.1.2 Sandblast Area AOPC

Tables N-11 through N-15 of Appendix N present the results of the screening for individual COIs evaluated for terrestrial plants, soil invertebrates, birds, mammals, and aquatic organisms. Tables N-16 through N-20 provide the results of the toxicity-based screening analysis that involved an evaluation of the cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

Terrestrial Plants - Seven metals (antimony, arsenic, chromium, lead, nickel, selenium and zinc), o-xylene (shallow soils only), PCE (shallow soils only), LPAHs (shallow soils only) and HPAHs have toxicity ratios greater than 1.0 (Table N-11) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the plant community at the Sandblast Area AOPC.

Chromium, lead, nickel, zinc (surface soils only), PCE (shallow soils only), and HPAHs (four in surface soils and six in shallow soils) contribute to a cumulative risk greater than 1.0 (Table N-16). These chemicals were already identified as CPECs based on the individual COI screening evaluation.

Soil Invertebrates - Five metals (arsenic, chromium, lead, nickel, and zinc), and HPAHs have toxicity ratios greater than 1.0 (Table N-12) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the soil invertebrate community at the Sandblast Area AOPC. To be consistent with the EcoSSL guidance, total HPAHs (and total LPAHs) were screened against the corresponding SLVs, and the individual HPAHs were evaluated from the perspective of their contribution to the toxicity ratio for total HPAHs.

Only chromium and zinc contribute to a cumulative risk greater than 1.0 (Table N-17), which was already identified as CPECs based on the individual COI screening evaluation.

Birds - Six metals (antimony, cadmium, chromium, lead, nickel, and zinc), Total DDTs (surface soil only), and B2EHP have toxicity ratios greater than 1.0 (Table N-13) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual birds at the Sandblast Area AOPC. All PAHs except naphthalene, as well as 21 other bioaccumulative COIs, were retained as CPECs due to the lack of SLVs that address the dietary pathway.

Antimony, cadmium, chromium, lead, zinc (shallow soils only), and B2EHP contribute to a cumulative risk greater than 1.0 (Table N-18), which were already identified as CPECs based on the individual COI screening evaluation.

Mammals - Four metals (antimony, cadmium, chromium, and lead), dibenzofuran, and HPAHs have toxicity ratios greater than 5.0 (Table N-14) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in mammal populations at the Sandblast Area AOPC. To be consistent with the EcoSSL guidance, total HPAHs (and total LPAHs) were screened against the corresponding SLVs, and the individual HPAHs were evaluated from the perspective of their contribution to the toxicity ratio for total HPAHs. There are 21 bioaccumulative COIs that were retained as CPECs due to the lack of SLVs that address the dietary pathway. Even though the majority of individual HPAHs have toxicity ratios greater less than 5.0, all HPAHs were retained as CPECs for mammals because the total HPAH toxicity ratio is above 5.0 and all are potentially bioaccumulative.

Antimony (surface soils only), chromium, dibenzofuran, and total HPAHs contribute to a cumulative risk greater than 5.0 (Table N-19), which were already identified as CPECs based on the individual COI screening evaluation.

Aquatic Organisms and Aquatic-Dependent Wildlife - The toxicity ratio for cis-1,2-DCE is only slightly greater than 1.0 (at 1.12, Table N-15), and since this is the only CPEC with a detection above the benchmark, no further investigation is recommended to assess the potential for adverse effects to aquatic organisms or wildlife that could be exposed to surface water that has been impacted by COIs in groundwater of the Sandblast Area AOPC. Arsenic, four LPAHs, and five HPAHs are bioaccumulative COIs that were retained as a CPECs due to the lack of SLVs that address the dietary pathway.

Calcium, magnesium, monobutyltin, 1,1-trichloroethane, carbon disulfide, cis-1,2-DCE, and benzo(a)pyrene (only direct push groundwater data available for this HPAH) contribute to a cumulative risk greater than 1.0 (Table N-20). With the exception of cis-1,2-DCE, none of these CPECs have individual toxicity ratios above 1.0. The sum of the toxicity ratios for all PAHs in groundwater is less than 1.0 (sum toxicity ratio of 0.7). Due to the very low toxicity ratios, the fact that two of these CPECs are essential nutrients, and three are VOCs that would not be expected to persist in surface water or bioaccumulate, no further investigation is recommended.

12.3.4.1.3 Pistol Range AOPC

Tables N-21 through N-27 of Appendix N present the results of the screening for individual COIs evaluated for terrestrial plants, soil invertebrates, birds, mammals, aquatic organisms, and the two receptor groups potentially exposed to lagoon sediment (benthic invertebrates exposed via direct contact and fish and wildlife exposed through bioaccumulation). Tables N-28 through N-34 provide the results of the toxicity-based screening analysis that involved an evaluation of the cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

Terrestrial Plants – Lead and zinc have toxicity ratios greater than 1.0 (Table N-21) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the plant community at the Pistol Range AOPC.

Only lead contributes to a cumulative risk greater than 1.0 for terrestrial plants (Table N-28), which was already identified as a CPEC based on the individual COI screening evaluation.

Soil Invertebrates - Zinc has a toxicity ratio greater than 1.0 (Table N-22) and requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in the plant community at the Pistol Range AOPC.

Zinc also contributes to a cumulative risk greater than 1.0 for terrestrial plants (Table N-29).

Birds - Lead and zinc have toxicity ratios greater than 1.0 (Table N-23) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual birds at the Pistol Range AOPC. Of these two CPECs, only lead has a toxicity ratio greater than 5.0.

Only lead contributes to a cumulative risk greater than 1.0 (Table N-30), which was already identified as a CPEC based on the individual COI screening evaluation.

Mammals - Lead has a toxicity ratio greater than 5.0 (Table N-24) and requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in mammal populations at the Pistol Range AOPC.

No individual COI contributes to a cumulative risk greater than 5.0 for mammals (Table N-31).

Aquatic Organisms and Aquatic-Dependent Wildlife - No toxicity ratios for groundwater of the Pistol Range AOPC are greater than 1.0 (Table N-25). Zinc is the only bioaccumulative COI that was retained as a CPEC due to the lack of SLVs that address the dietary pathway.

No individual COI contributes to a cumulative risk greater than 1.0 for groundwater (Table N-32). Since zinc was already evaluated for its potential to bioaccumulate in the ERA for the River OU (Section 12.5), no further investigation of groundwater at the Pistol Range AOPC is recommended.

Benthic Invertebrates - Zinc has a toxicity ratio slightly greater than 1.0 (1.41) for the benthic invertebrate community at the lagoon adjacent to the Pistol Range AOPC (Tables N-26). Lead and zinc contribute to a cumulative risk greater than 1.0 for the benthic community (Table N-33). However, the individual toxicity ratio for lead is below 1.0. As discussed in the RI/FS MP (URS 2007a), sediment samples from the lagoon were collected to determine if any COIs that could have originated from the former Pistol Range AOPC should be added to the list of COIs evaluated for the River OU. Both lead and zinc were already included in the list of COIs evaluated for their potential to bioaccumulate in the ERA for the River OU (Section 12.5), so no further action was required.

Fish and Aquatic-Dependent Wildlife - The maximum detected concentrations of lead and zinc in lagoon sediment are greater than the Reference Area 95% UPLs (Tables N-27 and N-34), which were used in the absence of sediment SLVs that are protective of fish and wildlife. As discussed in the RI/FS MP (URS 2007a), these sediment samples were collected to determine if any COIs that could have originated from the former Pistol Range AOPC should be added to the list of COIs evaluated for the River OU. Both lead and zinc were already included in the list of COIs evaluated for their potential to bioaccumulate in the ERA for the River OU (Section 12.5), so no further action was required.

12.3.4.1.4 Bulb Slope AOPC

Tables N-35 through N-38 of Appendix N present the results of the screening for individual COIs evaluated for terrestrial plants, soil invertebrates, birds, and mammals. Tables N-39 through N-42 provide the results of the toxicity-based screening analysis that involved an

evaluation of the cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

Terrestrial Plants – Lead and mercury have toxicity ratios greater than 1.0 (Table N-35) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the plant community at the Bulb Slope AOPC.

These two metals also contribute to a cumulative risk greater than 1.0 for terrestrial plants (Table N-39), and were already identified as CPECs based on the individual COI screening evaluation.

Soil Invertebrates - Mercury has a toxicity ratio greater than 1.0 (Table N-36) and requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in the soil invertebrate community at the Bulb Slope AOPC.

Mercury also contributes to a cumulative risk greater than 1.0 for soil invertebrates (Table N-40) and was already identified as CPECs based on the individual COI screening evaluation.

Birds - Lead and mercury have toxicity ratios greater than 1.0 (Table N-37) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual birds at the Bulb Slope AOPC. Both of these CPECs, have a toxicity ratio greater than 5.0.

Lead and mercury also contribute to a cumulative risk greater than 1.0 (Table N-41) and were already identified as CPECs based on the individual COI screening evaluation.

Mammals - Lead has a toxicity ratio greater than 5.0 (Table N-38) and requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in mammal populations at the Bulb Slope AOPC.

No individual COI contributes to a cumulative risk greater than 5.0 for mammals (Table N-42).

12.3.4.1.5 All Four AOPCs Combined

Tables N-43 and N-44 of Appendix N present the results of the screening for individual COIs evaluated for birds and mammals that have home ranges equal to or larger than the size of the entire Upland OU and could, therefore, forage over all four AOPCs. Tables N-45 and N-46 provide the results of the toxicity-based screening analysis that involved an evaluation of the cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

Birds - Seven metals (antimony, cadmium, chromium, lead, mercury, nickel and zinc), two herbicides, and B2EHP have toxicity ratios greater than 1.0 (Table N-43) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual birds over the four AOPCs combined. Of these ten CPECs, antimony, chromium, lead, mercury, MCPP (an herbicide), and B2EHP have toxicity ratios greater than 5.0. All PAHs except naphthalene, as well as 18 other bioaccumulative COIs, were retained as CPECs due to the lack of SLVs that address the dietary pathway.

Antimony, chromium, lead, mercury (surface soils only), MCPP, and B2EHP contribute to a cumulative risk greater than 1.0 (Table N-45), which were already identified as CPECs based on the individual COI screening evaluation.

Mammals - Four metals (antimony, cadmium, chromium, and lead), two herbicides, and total HPAHs have toxicity ratios greater than 5.0 (Table N-44) and require further investigation in the

risk interpretation section to assess their potential to elicit adverse effects in mammal populations over the four AOPCs combined. To be consistent with the EcoSSL guidance, total HPAHs (and total LPAHs) were screened against the corresponding SLVs, and the individual HPAHs were evaluated from the perspective of their contribution to the toxicity ratio for total HPAHs. There are 18 bioaccumulative COIs that were retained as CPECs due to the lack of SLVs that address the dietary pathway. Even though not all HPAHs have toxicity ratios greater than 5.0, all were retained as CPECs for mammals because the toxicity ratio for Total HPAHs is above 5.0 and all of these individual HPAHs are potentially bioaccumulative.

MCPP contributes to a cumulative risk greater than 5.0 (Table N-46), which were already identified as CPECs based on the individual COI screening evaluation.

12.3.4.2 Uncertainty Assessment

Uncertainty and the relative degree of such uncertainty should be considered when interpreting the results of the ERA. Uncertainty is introduced at each step of the process, and occurs because risk assessment is complex and requires the integration of many factors:

- Fate and transport of constituents in a variety of different and variable environments
- Selection of EPCs representative of actual exposure experienced by mobile receptors
- Potential for adverse health effects in ecological receptors as extrapolated from laboratory bioassays for which SLVs are often based
- Probability of adverse effects on ecological receptors is highly variable based on genetics, life stage, and trophic level.

Specific sources of uncertainty for this Level II ERA are presented in Appendix O.

12.3.4.3 Risk Interpretation

In this final phase of the risk characterization process, the quantitative and qualitative components of the risk screening (i.e., toxicity ratios) and uncertainty assessment are evaluated to gain a better understanding of the actual potential for ecological risk. Multiple lines of evidence are considered during risk interpretation to identify actual risk drivers at the site and to develop a supportable recommendation for risk managers to review. The outcome of the risk characterization will constitute the basis of remedial decisions for the protection of ecological receptors and risk driving exposure pathways.

For each AOPC and receptor, the CPECs identified in the previous section with toxicity ratios greater than 5.0 for mammals and toxicity ratios greater than 1.0 for all other receptors are plotted in Figures 12-6 through 12-17, and discussed in the text below. Those CPECs where a limited number of exceedances were noted (e.g., zinc for plants in the Landfill AOPC) were not included on the spatial distribution maps and the rationale for their exclusion is discussed prior to discussing the other CPECs.

To summarize the risk screening process, first the SLVs protective of ecological receptors were compared to the EPCs (i.e., 95% UCLs for mobile receptors and maximum concentrations for stationary receptors) for each analyte to identify CPECs that could require further assessment. The magnitude of the exceedance, detection frequency, confidence in the SLV, and other lines of evidence were considered to identify those CPECs that warrant a more rigorous evaluation of the data. For this whittled down list of CPECs, the spatial distribution of the concentrations relative

to the SLVs was assessed through a review of this information on figures presented in this section. Based on this weight of evidence approach, those CPECs that truly warrant additional investigation or risk management are identified and discussed below.

12.3.4.3.1 Landfill AOPC

Terrestrial Plants - Arsenic (shallow soil only), lead, mercury, zinc, Total LPAHs, and Total HPAHs have toxicity ratios greater than 1.0 (Table N-1) and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the plant community at the Landfill AOPC. Arsenic, lead, and zinc were detected in all soil samples, and mercury was detected in approximately 80% of the samples (Table 9-1). Maximum concentrations of lead, zinc, and most LPAHs were detected below 1 foot bgs, while the maximum concentrations of arsenic, mercury and most HPAHs were detected at the surface. As shown in Tables 8-1, L-1, and L-2, all of the LPAHs and HPAHs were detected at concentrations statistically higher than the Reference Area data.

No further assessment of arsenic is recommended for plants, given that only the maximum concentration, which was collected below the surface, exceeded the SLV and the toxicity ratio is low (1.67). In addition, concentrations of arsenic in surface soils are statistically lower than the Reference Area data (Table L-1).

No further assessment of zinc is recommended for plants. Seven surface soil and a single shallow soil sample exceeded the SLV for plants. The toxicity ratio based on the maximum surface soil concentration is 3.97, and the remaining few surface soil exceedances result in low sample-specific toxicity ratios ranging from 1.13 to 1.64. Only the maximum zinc concentration, which was collected below the surface, exceeded the 5 times the SLV (BIL22). In addition, no sensitive plant species exist at the Landfill, which is maintained as goose pasture (Section 3.1.6.1.1), and zinc is an essential nutrient for plants (USEPA 2005-2008; Efroymson et al. 1997a).

The toxicity ratio for Total LPAHs of 1.87 for the 0 to 1 foot interval and 3.48 for the 0 to 3 feet interval are driven primarily by concentrations of phenanthrene, and secondarily by concentrations of anthracene (Table N-1). Three samples had concentrations in exceedance of the SLV for plants (BIl04SSI, BIL18, and L-02), and no samples have concentrations in exceedance of 5 times the SLV (Table H-1). The highest concentration of LPAHs occurred at the Gully Test Pit (BIL18). No further assessment of LPAHs is recommended for plants, given the low and infrequent exceedances of the SLV.

Figure 12-6 shows observed soil concentrations compared to SLVs for lead, mercury, and HPAHs for plants. One detected concentration of mercury was between 10 and 50 times the SLV (at the mercury vapor-lamp test pit). Three lead samples collected at the surface and five collected from the subsurface had concentrations in exceedance of the corresponding SLV. Concentrations exceeding 5 times the SLV were observed at the Lead Hotspot Test Pit #1, one location in the Gully Test Pit, and one just north of the Gully Test Pit. The highest concentrations of HPAHs (greater than 50 times the SLV) also occurred at Lead Hotspot Test Pit #1 and the Gully Test Pit, with some lower level exceedances at a few locations outside of these areas.

Based on the assessment for plants at the Landfill AOPC, it is possible that localized impacts could occur from exposure to the primary risk drivers: lead, mercury, and HPAHs. Potential effects to the terrestrial plant community as a whole are likely overestimated, as only a few individual plants (i.e., grasses) are exposed to the maximum concentration of each CPEC

throughout their life span. In addition, the studies upon which terrestrial plant SLVs were derived typically use crops as the test species, and sensitivity levels of undomesticated plant species are likely to be different from crops species. Furthermore, the types of plants found at the Landfill AOPC (ruderal vegetation and some remaining ornamental plants) are not considered sensitive species. Based on these considerations, adverse effects to the terrestrial plant community at the Landfill AOPC are not expected to occur. However, these three CPECs are recommended for further investigation in a Level III BERA because they been identified as CPECs for other receptors at the Landfill as well as plants.

Soil Invertebrates - Two metals (mercury and zinc), ethylbenzene (shallow soil only), carbazole, and total HPAHs had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the soil invertebrate community at the Landfill AOPC. Zinc was detected in all soil samples, and mercury was detected in approximately 80% of the samples (Table I-1). Ethylbenzene was detected in 6% of soil samples collected from 0 to 1 foot bgs, and in 5% of samples collected from 0 to 3 feet bgs (not a CPEC for this depth interval). Carbazole had detection frequencies of 70% (0 to 1 foot bgs) and 72% (0 to 3 feet bgs). The maximum concentrations of zinc and carbazole were detected below 1 foot bgs, while the maximum concentrations of mercury, ethylbenzene, and most HPAHs were detected at the surface. As shown in Tables 8-1, L-1, and L-2, all of the HPAHs were detected at concentrations statistically higher than the Reference Area data.

Toxicity ratios for zinc were 5.29 and 9.50 for surface and shallow soil, respectively. However, as shown in Figure 12-7, the majority of concentrations of zinc above the SLV were between 1 and 5 times greater than the SLV for soil invertebrates (12 samples). Only two locations (maximum surface and shallow) had concentrations of zinc between 5 and 10 times the SLV, one of which is below the surface. No further assessment of zinc is recommended for soil invertebrates, given the low-level exceedances of the SLV, lack of special status soil invertebrate species at the Landfill AOPC, and because zinc is an essential nutrient (USEPA 2005-2008; and Efroymson et al. 1997b).

The toxicity ratio for ethylbenzene was 1.19, and the toxicity ratios for carbazole were 1.17 and 1.26 for surface and shallow soil, respectively (Table N-2). The only detection of ethylbenzene out of 18 samples collected from 0 to 1 foot bgs exceeded the SLV. Two of 29 samples from the 0 to 3 feet depth interval had concentrations of carbazole slightly greater than the SLV. No further assessment of ethylbenzene and carbazole are recommended for soil invertebrates, given the low and infrequent exceedances of their SLVs and lack of special status soil invertebrate species at the Landfill AOPC.

Figure 12-7 also shows observed soil concentrations compared to SLVs for mercury and HPAHs for soil invertebrates. Concentrations of mercury were greater than the SLV in 15 samples. Of these 15 SLV exceedances, three samples had concentrations between 5 and 10 times the SLV and two had concentrations between 10 and 50 times the SLV. Four of the highest detections of mercury occurred at the mercury vapor-lamp test pit, and the other occurred just east of the Pesticide/Herbicide Wash Area.

Concentrations of HPAHs were greater than the SLV in 12 samples (Figure 12-7). Of these 12 SLV exceedances, three had concentrations between 10 and 50 times the SLV, while the remaining exceedances were less than 5 times the SLV. The highest concentrations of HPAHs (between 10 and 50 times the SLV) occurred at Lead Hotspot Test Pit #1 and the Gully Test Pit.

Based on the assessment for invertebrates at the Landfill AOPC, it is possible that localized impacts could occur from exposure to the primary risk drivers: mercury and HPAHs. Effects to the soil invertebrate community are likely to be overestimated due to the assumption that these organisms are exposed to the maximum concentration of each CPEC throughout their life span. No sensitive invertebrate species are known to be present at the Landfill AOPC. Based on these considerations, adverse effects to the soil invertebrate community at the Landfill AOPC are not expected to occur. Nonetheless, mercury and HPAHs are recommended for further investigation in a Level III BERA because they been identified as CPECs for other receptors at the Landfill as well as soil invertebrates.

Birds - Five metals (antimony, cadmium, lead, mercury, and zinc), two herbicides, and B2EHP had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in individual birds at the Landfill AOPC. Antimony, lead, mercury, zinc (shallow soils only) and MCPP (an herbicide) had toxicity ratios greater than 5.0 and were assessed for potential impacts to bird populations. The approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls, but these special-status species are not likely to forage at the 1.36-acre Landfill AOPC. Owls have not been documented to occur on the island, and bald eagles have been seen roosting in the vicinity of the Landfill AOPC, but these piscivorous birds would be much more likely to forage in the adjacent River OU. Piscivorous birds were evaluated in the Level II Screening Assessment for the River OU (Section 12.5).

In the absence of an avian SLV for antimony, the Reference Area UPL for soil was used in the screening evaluation. Antimony is not considered bioaccumulative (Table J-6) and therefore, would not be expected to be present in dietary tissues at levels of concern for birds. However, antimony was identified as a CPEC for mammals at the Landfill and will be included in the Level III BERA. In the Level III BERA, antimony will be evaluated for all receptors at the Landfill AOPC for consistency purposes.

Based on the low toxicity ratios for cadmium (1.26 for the 0 to 1-foot interval and 1.52 for the 0 to 3-feet interval), high confidence in the SLV (USEPA EcoSSL), and absence of protected species of terrestrial birds, no further evaluation is recommended for cadmium.

The two herbicides with toxicity ratios greater than 1.0 were dichloroprop and MCPP. These CPECs were detected in two of 14 samples (14% detection frequency) for the 0 to 3-feet interval (Table I-1). In the absence of avian toxicity data for these herbicides, the SLV for Total DDTs was used as a surrogate. Use of DDT as a surrogate for these herbicides is expected to be very conservative due to the high bioaccumulation potential associated with DDTs, which is the basis of the SLV, compared to that of these two herbicides, which are not expected to bioaccumulate (Section 7.3 and Table J-6; log $K_{ow} < 3.5$). For these reasons, no further evaluation is recommended for dichloroprop or MCPP.

Figure 12-8 shows a sample by sample comparison to SLVs for the following CPECs that remain for birds: lead, mercury, zinc, and B2EHP. As described in Section 5.1.1, the two mercury vapor-lamp test pit samples shown in the figure (BIL28TPM and BIL29TPM) were collected from stockpiled soils that were used to backfill their respective excavation pits. The soil may have been placed anywhere within the 0-10 feet bgs depth of the test pits. Since there is no way to assign a depth at which the results for these samples occur, both samples were used to assess risk to ecological receptors exposed to surface and shallow soils.

Low toxicity ratios were calculated for zinc (2.89 for the 0 to 1-foot interval and 5.82 for the 0 to 3-feet interval) – these ratios were calculated using the Reference Area UPL as the SLV because the USEPA EcoSSL for zinc is below the site-specific UPL.

As shown on the figure, the majority of locations at the Landfill AOPC had zinc concentrations between 1 to 5 times the UPL. Only one location east of Lead Hot Spot Test Pit # 1 (BIL05SSI) had a detected zinc concentration between 5 to 10 times the UPL, and only the maximum detected concentration from the Gully Test Pit (BIL22) was between 10 and 50 times the UPL. The later sample is from a depth (1 to 3 ft bgs) where exposure to birds is reduced. Given that this sample was detected below the surface and because zinc has a low toxicity ratio for surface soil and is an essential nutrient for birds (metabolically regulated; USEPA 2005-2008), no further evaluation is recommended for zinc.

Only two detected concentrations of B2EHP were above the soil SLV. These samples, with concentrations between 1 to 5 times the SLV, were collected at the Lead Hot Spot Test Pit #1 and adjacent to that test pit. The toxicity ratios for B2EHP were relatively low (2.15 for the 0 to 1-foot interval and 1.42 for the 0 to 3-feet interval). Based on the low frequency of SLV exceedances and low magnitude of these exceedances, no further evaluation is recommended for B2EHP.

As shown on Figure 12-8, several locations had concentrations of lead and mercury in exceedance of the avian SLVs. For lead, several locations are between 1 to 5 times the SLV, eight locations are between 5 to 10 times the SLV, seven locations were between 10 to 50 times the SLV, and a single location (subsurface soil) was greater than 50 times the SLV. For mercury, the majority of the samples had concentrations between 1 to 5 times the SLV, two locations were between 5 to 10 times the SLV, two locations were between 10 to 50 times the SLV, and a single location had a concentration greater than 50 times the SLV.

The highest concentrations of these CPECs in soil (10 times or 50 times greater than the SLVs) were detected in the Mercury Vapor-Lamp Test Pit, Gully Test Pit, Lead Hot-Spot Test Pit #1, and a sample collected just outside of the Pesticide/Herbicide Wash Area. Due to the elevated toxicity ratios for lead and mercury, which are potentially bioaccumulative (mercury is known to bioaccumulate), and the fact that several locations have concentrations greater than the SLVs, further assessment or remediation of the locations with elevated lead and mercury is recommended.

In a Level III BERA to evaluate exposure to lead and mercury in soil by birds, the following site-specific factors should be considered:

- First, as discussed above, the approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls, but these special-status species are not likely to forage at the 1.36 acre Landfill AOPC. For this reasons, protection of terrestrial bird species at the population-level would be emphasized in the Level III BERA for the Upland OU.
- Second, the site-specific Reference UPLs were greater than the risk-based soil SLVs (EcoSSL for lead and Avian PRG for mercury) and, therefore, the SLVs were replaced by the UPLs in the screening evaluation. In addition to evaluating specific bird target species and using literature-based BAFs to estimate dose, the contribution of background levels of metals would also be considered to better understand site-related dose contribution.

- Third, the size of the Landfill AOPC relative to the size of a birds' home range would be factored into the daily dose estimation.

Mammals - Four metals (antimony, lead, mercury, and zinc), two herbicides, dibenzofuran and HPAHs had toxicity ratios greater than 5.0 and were assessed for their potential to elicit adverse effects in mammal populations at the Landfill AOPC. As shown in Tables 8-1, L-1, and L-3, all of the HPAHs were detected at concentrations statistically higher than the Reference Area data.

The two herbicides with toxicity ratios greater than 5.0 were dichloroprop and MCPP. As discussed above for birds, these CPECs were detected in two of 14 samples (14% detection frequency for the 0 to 3-feet interval; Table I-1). In the absence of chemical-specific SLVs for these herbicides, the mammal SLV for Total DDTs was used as a surrogate. Use of DDT as a surrogate for these herbicides is expected to be very conservative due to the high bioaccumulation potential associated with DDTs, which is the basis of the SLV, compared to that of the two herbicides, which are not expected to bioaccumulate (Table J-6; log K_{ow} < 3.5). For these reasons, no further evaluation is recommended for of dichloroprop and MCPP.

Figure 12-9 shows a sample by sample comparison to SLVs for the following CPECs that remain for mammals: antimony, lead, mercury, zinc, dibenzofuran, and total HPAHs. Several locations had concentrations of these CPECs in exceedance of the mammal SLVs, and the highest concentrations of these CPECs in soil (10 times or 50 times greater than the SLVs) were detected in the Mercury Vapor-Lamp Test Pit, the Gully Test Pit, Lead Hot Spot Test Pit #1, and a couple of locations in and near the Pesticide/Herbicide Wash Area. There were also a few elevated detections just outside the boundaries of the Gully Test Pit and Lead Hot Spot Test Pit #1.

Based on the low toxicity ratios for zinc (<5.0 for the 0 to 1-foot interval and 5.28 for the 0 to 3-feet interval), high confidence in the SLV (USEPA EcoSSL), and because zinc is an essential nutrient for mammals (metabolically regulated), no further evaluation is recommended for zinc.

Dibenzofuran in soil does have the potential to bioaccumulate (log K_{ow} < 3.5), but little toxicity data exist to evaluate the consumption pathway for mammals. TRVs could not be found in USEPA or Oak Ridge National Laboratory (ORNL) publications or databases, nor does USEPA's Integrated Risk Information System (IRIS) database provide an oral reference dose for dibenzofuran. Given the lack of toxicity data, a meaningful Level III BERA is not possible for dibenzofuran, and no further evaluation is recommended for this COPC. Furthermore, as shown on Figure 12-9, dibenzofuran co-occurred with elevated detections of the other risk-driver CPECs at the following main areas of the Landfill: Lead Hot Spot Test Pit #1 (lead and HPAHs), Mercury Vapor-Lamp Test Pit (antimony, mercury and HPAHs), and Gully Test Pit (lead, and HPAHs). A few other locations just outside of the boundaries of the Lead Hot Spot and Gully Test Pits demonstrate co-occurrence of dibenzofuran with these other CPECs. Since antimony, lead, mercury, and HPAHs are recommended for further investigation and there is more confidence in the available data for these CPECs, lack of a site-specific evaluation of dibenzofuran is a manageable uncertainty for the Upland OU ERA.

Due to toxicity ratios greater than 10 times the SLV for antimony, lead, mercury, and total HPAHs, which are potentially bioaccumulative (with the exception of antimony), and the fact that several locations had concentrations greater than the SLVs, further investigation of these CPECs is recommended in the form of a Level III BERA or remediation of the locations with elevated concentrations.

In a Level III BERA to evaluate exposure to antimony, lead, mercury, and HPAHs in soil by mammals, site-specific factors should be considered. In addition to evaluating specific mammal target species and using literature-based BAFs to estimate dose, the contribution of background levels of metals would also be considered to better understand site-related dose contribution. Also, the size of the Landfill AOPC relative to the size of a mammals' home range would be factored into the daily dose estimation.

Aquatic Organisms and Aquatic-Dependent Wildlife - Four metals (barium, iron, manganese and zinc) and B2EHP had toxicity ratios greater than 1.0 for groundwater and were assessed for their potential to elicit adverse effects in individual aquatic organisms or wildlife that could be exposed to surface water that has been impacted by COIs in groundwater of the Landfill AOPC. Barium, iron, manganese, and zinc had toxicity ratios greater than 1.0 for seep water, of which barium and manganese had toxicity ratios above 5.0. No CPECs were identified in the surface water samples that are co-located with the seep samples.

Based on the low toxicity ratios for zinc in groundwater and seep water (2.56 and 1.12, respectively), and the absence of a detection in co-located surface water, and because zinc is an essential nutrient (metabolically regulated), no further evaluation is recommended for zinc.

Figure 12-10 compares observed concentrations to SLVs for aquatic biota for the following CPECs: barium, iron, manganese, and B2EHP. The direction of groundwater flow beneath the Landfill AOPC is to the north. B2EHP was detected above the SLV in two groundwater wells (MW-1 and MW-2). MW-2 is the well farthest from the shoreline (south) of the River OU, and MW-1 is approximately 60 feet from the shoreline. This CPEC was not detected in other wells located closer to the shoreline and was not detected in seep or co-located surface water. Based on these reasons and given the generally low toxicity ratio for groundwater (1.57), no further evaluation is recommended for B2EHP.

Neither USEPA National Recommended Water Quality Criteria (NRWQC; USEPA 2009) nor DEQ WQC (Table 33A) were available for barium and manganese. Therefore, DEQ's Level II SLVs for surface water were used, which are Tier II secondary chronic values (Suter and Tsao 1996). Confidence in these surface water SLVs is lower than in SLVs derived from the NRWQC or WQC. The surface water SLV used for iron is a DEQ WQC.

Dissolved barium concentrations exceeded the SLV in three groundwater samples (Figure 12-10). The maximum detected dissolved phase barium concentration occurred in a seep sample collected in 2000 ("SEEP"). In the absence of dissolved barium data for wells MW-1 and MW-5 through MW-9, total barium concentrations from these wells are shown on Figure 12-10 for these wells. Using data from unfiltered samples contributes to an overestimate of risk to aquatic biota since the SLVs are typically based on the dissolved phase, as this is the most bioavailable fraction. All dissolved and total concentrations of barium in Landfill and Reference Area groundwater exceeded the surface water SLV for barium, illustrating the conservativeness of the SLV.

Iron is well known to occur in leachate from landfills, and was detected in Landfill AOPC groundwater at concentrations exceeding the surface water SLVs in 15 samples representing four monitoring wells (Figure 12-10). It was also detected at approximately three times the SLV in the seep sample collected in 2000. The toxicity ratios for groundwater and seep water were 31 and 3.21, respectively (Table N-5), and the mean concentration of iron in groundwater generated a toxicity ratio of 9.8 (the mean seep concentration is below the SLV). Iron was not detected

above the SLV in the seep samples collected in 2008 and 2009 (S2 and S4). The co-located surface water samples result in an iron toxicity ratio of 0.0092 (Table N-5). Given the low detections of iron in seep and co-located surface water, which are more likely to represent actual exposure by aquatic biota, and because iron is an essential nutrient, no further evaluation is recommended for iron.

Manganese concentrations were above the SLV in several of the groundwater wells, and were co-located with elevated levels of barium and iron. Manganese was approximately ten times the SLV in the seep sample collected in 2000. The toxicity ratios for groundwater and seep water were 29.2 and 12.3, respectively (Table N-5), and the mean concentrations of manganese (dissolved) in groundwater and seep water generated toxicity ratios of 9.0 and 2.4, respectively. Manganese was not detected above the SLV in the seep samples collected in 2008 and 2009 or in the co-located surface water samples (toxicity ratio of 0.00842). Given the low detections of manganese in seep and co-located surface water, which are more likely to represent actual exposure by aquatic biota, no further evaluation is recommended for manganese.

Concentrations of iron and manganese measured in the seep sample collected in 2000 were two orders of magnitude higher than those measured in 2008 and 2009. Although barium was not analyzed for in the new seep samples, it is likely that concentrations of this CPEC have also decreased. Based on this trend in the data, the low concentrations of CPECs in seep and surface water samples compared to the groundwater samples from interior of the Landfill AOPC, and the other lines of evidence discussed above for each CPEC, no further investigation of groundwater at the Landfill AOPC is recommended to protect aquatic biota.

12.3.4.3.2 Sandblast Area AOPC

Terrestrial Plants - Seven metals (antimony, arsenic, chromium, lead, nickel, selenium and zinc), o-xylene (shallow soils only), PCE (shallow soils only), LPAHs (shallow soils only) and HPAHs have toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the plant community at the Sandblast Area AOPC. Chromium, lead, nickel, and zinc were detected in all soil samples, while arsenic was detected in 98% to 99% of the samples (Table I-2). Antimony was detected in 71% to 73% of the samples, and selenium was detected 52% to 57% of the samples. o-xylene and PCE were detected in 11% of the samples collected from the 0 to 3 foot depth interval. LPAHs and HPAHs were detected in nearly all samples. Maximum concentrations of all seven metals were detected at the surface, while the maximum concentrations of o-xylene, PCE and several PAHs were detected below 1 foot bgs (maximum concentrations of some individual PAHs were detected at the surface). As shown in Tables 8-1, L-1, and L-2, all of the PAHs were detected at concentrations statistically higher than the Reference Area data.

Four samples had antimony concentrations in exceedance of the plant SLV, all of which were detected in the surface soil interval. The maximum concentration (SBB12) resulted in a relatively low toxicity ratio of 2.74. Therefore, adverse effects to the terrestrial plant community at the Sandblast AOPC are not expected to occur. However, antimony is recommended for further investigation in a Level III BERA because it was also identified as a CPEC for mammals at the Sandblast Area AOPC (see below). In the Level III BERA, antimony will be evaluated for all receptors at the Sandblast Area AOPC for consistency purposes.

No further assessment of arsenic is recommended for plants, given the low, limited exceedances of the SLV and lack of special status plant species at the Sandblast Area AOPC. Only the three

highest detected concentrations of arsenic exceeded the plant SLV (DSA07, DSA11, and SBB18), all of which were detected in the surface soil interval. The maximum concentration, which was detected near the southwest corner of the current HSMA (SBB18), resulted in a relatively low toxicity ratio of 4.49.

No further assessment of selenium is recommended for plants, given the low toxicity ratio of 1.73 and lack of sensitive plant species at the Sandblast Area AOPC. Although selenium is one of the few metals with the potential for significant bioaccumulation, it was not identified as a CPEC for birds and mammals.

No further assessment of LPAHs is recommended for plants, given the low, single exceedance of the SLV and lack of special status plant species at the Sandblast Area AOPC. The toxicity ratio for Total LPAHs of 1.31 for the 0 to 3 feet interval is driven primarily by concentrations of phenanthrene, and secondarily by concentrations of anthracene (Table N-11). Only the maximum concentration, which was detected below the surface, exceeded the SLV for plants. The toxicity ratio for the 0 to 1 foot depth is 0.569.

No further evaluation of o-xylene and PCE is recommended for plants, given that only the maximum concentration of each exceeded the SLVs, and were located in a single sample below the surface. In addition, the toxicity ratios for the 0 to 1 foot depth are notably low at 0.00018 (o-xylene) and 0.00031 (PCE) (Table N-11).

Figure 12-11 shows a sample by sample comparison to SLVs for the following CPECs for plants:, chromium, lead, nickel, zinc, and HPAHs.

The toxicity ratio for zinc based on the maximum concentration, which was detected in the surface soil interval, is 7.25 (Table N-12). When the 95% UCL (212 mg/kg) or mean (173 mg/kg) zinc concentrations in the 0 to 1-foot interval are used, the toxicity ratio drops to 1.3 and 1.08, respectively. With the exception of the maximum concentration of zinc at SBB15, all remaining locations with exceedances of the SLV shown on Figure 12-11 have concentrations between 1 and 5 times the SLV. Therefore, no further assessment of zinc is recommended for plants, given the low exceedances of the SLV, lack of special status plant species at the Sandblast Area AOPC, high confidence in the SLV (USEPA EcoSSL), and the fact that zinc is an essential nutrient for plants.

Chromium concentrations exceeded 5 times the SLV at 25 surface locations, seventeen of which were between 10 and 50 times the SLV and three were greater than 50 times the SLV. Lead exceeded 5 times the SLV at 11 surface locations and 1 subsurface location, of which, only one surface location was between 10 and 50 times the SLV. Nickel exceeded 5 times the SLV at 16 surface locations, ten of which were between 10 and 50 times the SLV. The majority of the chromium, lead, and nickel exceedances occurred throughout the spent sandblast grit disposal area and surrounding CB-1.

Total HPAH concentrations exceeded 5 times the SLV at 10 surface locations, of which five had concentrations between 10 and 50 times the SLV, and one had a concentration greater than 50 times the SLV (HA-3). Total HPAH concentrations also exceeded the SLV at two subsurface locations, one of which had a concentration between 10 and 50 times the SLV, and one had a concentration greater than 50 times the SLV. The locations with elevated HPAH concentrations occur in the northeast portion of the equipment laydown area, adjacent to the current HMSA, adjacent to the roadway in the south, and within the area of erodible soils within the AOPC.

Based on the assessment for plants at the Sandblast Area AOPC, it is possible that impacts could occur from exposure to the primary risk drivers: chromium, lead, nickel, and HPAHs. However, the studies upon which terrestrial plant SLVs were derived typically use crops as the test species, and sensitivity levels of undomesticated plant species are likely to be different than crop species. Potential effects to the plant community are likely to be overestimated due to the assumption that these organisms are exposed to the maximum concentration of each CPEC throughout their life span. No sensitive plant species are known to be present at the Sandblast Area AOPC.

However, due to the elevated toxicity ratios for chromium, lead, nickel, and HPAHs, further investigation of these CPECs is recommended in the form of either a Level III BERA or remediation at the locations of highest elevations: the northeastern portion of the equipment laydown area, south of the current HMSA, within the central portion of the spent sandblast grit area, and around CB-1.

Soil Invertebrates - Five metals (arsenic, chromium, lead, nickel, and zinc), and HPAHs have toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the soil invertebrate community at the Sandblast Area AOPC. Chromium, lead, nickel and zinc were detected in all soil samples. Arsenic was detected in 98% to 99% of the samples, while the detections of individual HPAHs varied. Maximum concentrations of all five metals were detected at the surface, while the maximum concentration of total HPAHs was detected below 1 foot bgs. As shown in Tables 8-1, L-1 and L-2, all of the HPAHs were detected at concentrations statistically higher than the Reference Area data.

No further assessment of arsenic is recommended for soil invertebrates, given the low, single exceedance of the SLV and lack of special status invertebrate species at the Sandblast Area AOPC. Only the maximum concentration of arsenic exceeded the invertebrate SLV, resulting in a low toxicity ratio of 1.35.

Only the maximum concentration of lead exceeded the soil invertebrate SLV, resulting in a toxicity ratio of 1.92. Given the low, single exceedances of the SLV and lack of special status invertebrate species at the Sandblast Area AOPC, adverse effects to the soil invertebrate community are not expected to occur from exposure to lead. However, lead is recommended for further investigation if a Level III BERA is performed because it was identified as a CPEC for other receptors at the Sandblast Area AOPC as well as soil invertebrates.

Figure 12-12 shows a sample by sample comparison to SLVs for the following CPECs for soil invertebrates: chromium, nickel, zinc, and HPAHs.

No further assessment of nickel is recommended for soil invertebrates, given the low exceedances of the SLV (Figure 12-12) and lack of special status invertebrate species at the Sandblast Area AOPC. The toxicity ratio for nickel based on the maximum concentration is 3.79 (Table N-12), and when the 95% UCL (353 mg/kg) or mean (167 mg/kg) nickel concentrations for the 0 to 1-foot interval are used the toxicity ratio drops to 1.26 and 0.60, respectively. All locations with exceedances of the SLV shown on Figure 12-12 have concentrations between 1 and 5 times the SLV (primarily within Spent Sandblast Grit Disposal Area).

No further assessment of zinc is recommended for soil invertebrates, given the relatively low exceedances of the SLV, lack of special status soil invertebrate species at the Sandblast Area AOPC, high confidence in the SLV (USEPA EcoSSL), and the fact that zinc is an essential nutrient for invertebrates. The toxicity ratio for zinc based on the maximum concentration is 9.67

(Table N-12), and when the 95% UCL (212 mg/kg) or mean (173 mg/kg) zinc concentrations are used the toxicity ratio drops to 1.77 and 1.44, respectively.

Four samples had concentrations of total HPAHs greater than the SLV for soil invertebrates, and one sample had a concentration greater than 5 times the SLV. The toxicity ratios of 4.02 for surface soils and 5.84 for shallow soils are driven primarily by concentrations of fluoranthene and pyrene. Concentrations of chromium were greater than 5 times the SLV at 25 surface soil locations, of which sixteen were between 10 and 50 times the SLV and three were greater than 50 times the SLV. The majority of the chromium exceedances occurred throughout the spent sandblast grit disposal area and surrounding CB-1.

Based on the assessment for soil invertebrates at the Sandblast Area AOPC, it is possible that localized impacts could occur from exposure to the primary risk drivers: chromium, and to a lesser extent, HPAHs. Potential effects to the soil invertebrate community are likely to be overestimated due to the assumption that these organisms are exposed to the maximum concentration of each CPECs throughout their life span. No sensitive invertebrate species are known to be present at the Sandblast Area AOPC. Due to the elevated toxicity ratios for chromium, further investigation of this CPEC is recommended in the form of either a Level III BERA or remediation at the locations of highest elevations: south of the Current HMSA, within the central portion of the spent sandblast grit disposal area, and around CB-1.

Given the lower and less frequent exceedances of the SLV for HPAHs, the potential for adverse effects to the soil invertebrate community from exposure to HPAHs is expected to be lower than for chromium. However, HPAHs are recommended for further investigation if a Level III BERA is performed because they were identified as a CPEC for other receptors at the Sandblast Area AOPC as well as soil invertebrates.

Birds - Six metals (antimony, cadmium, chromium, lead, nickel, and zinc), Total DDTs (surface soil only), and B2EHP had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the individual birds at the Sandblast Area AOPC. Antimony, chromium, lead, and B2EHP had toxicity ratios greater than 5.0 and were assessed for potential impacts to bird populations.

In the absence of an avian SLV for antimony, the Reference Area UPL for soil was used in the screening evaluation. Antimony is not considered bioaccumulative (Table J-6) and therefore, would not be expected to be present in dietary tissues at levels of concern for birds. No further evaluation is recommended for antimony.

As stated previously in the Landfill AOPC risk interpretation, there are no protected species of terrestrial birds at the site. Based on the low toxicity ratios for nickel (1.68 for the 0 to 1-foot interval and 1.2 for the 0 to 3-feet interval), high confidence in the SLV (USEPA EcoSSL), and absence of protected species of terrestrial birds, no further evaluation is recommended for nickel.

The toxicity ratio for Total DDTs is essentially equivalent to 1.0 for the 0 to 1-foot interval (toxicity ratio of 1.029). 4,4'-DDT has the highest toxicity ratio of 0.347, and the toxicity ratios for the remaining two isomers are much lower (0.0078 for 4,4'-DDD and 0.0068 for 4,4'-DDE). The slight exceedance of 1.0 by the estimated concentration of Total DDTs is likely an artifact of the summation process. Based on the low toxicity ratios for Total DDTs, high confidence in the SLV (USEPA EcoSSL), and absence of protected species of terrestrial birds, no further evaluation is recommended for Total DDTs or the individual DDT isomers.

Figure 12-13 shows a sample by sample comparison to SLVs for the following CPECs that remain for birds: cadmium, chromium, lead, zinc, and B2EHP. The ratios for chromium, lead, and zinc were calculated using the Reference Area UPL as the SLV because the USEPA EcoSSLs for these metals are below the site-specific UPLs.

Low toxicity ratios were calculated for cadmium (4.16 for the 0 to 1-foot interval and 3.42 for the 0 to 3-feet interval) and zinc (2.96 for the 0 to 1-foot interval and 3.31 for the 0 to 3-feet interval) (Table N-13). As shown on the figure, the majority of locations at the Sandblast Area AOPC had concentrations of cadmium and zinc ranging between 1 to 5 times the SLV/UPL. Cadmium concentrations were between 5 and 10 times the SLV at three locations and between 10 and 50 times the SLV at three additional locations, all of which were located in the northeastern portion of the equipment laydown area. Zinc concentrations were between 5 and 10 times the UPL at a five scattered locations and between 10 and 50 times the UPL at a single location adjacent to the road east of the former sandblast building. Given that the equipment laydown area with the elevated cadmium concentrations is actively used and currently covered by equipment, the location with the maximum concentration of zinc is adjacent to an active roadway the fact that zinc is an essential nutrient for birds, and the low toxicity ratios, no further evaluation is recommended for cadmium or zinc. If, in the future, the equipment is removed and the habitat at the equipment laydown area is allowed to naturally restore, the potential for risk tor birds may need to be reevaluated.

As shown on Figure 12-13, B2EHP concentrations were between 1 and 5 times the SLV at eight surface soil locations and two subsurface soil locations. Only one surface soil location had a concentration of B2EHP between 10 and 50 times the SLV and only one surface soil sample had a concentration greater than 50 times the SLV, both of which were composite samples of the erodible area north of the former sandblast building. Many of the surface soil and several subsurface soil locations had concentrations of chromium and lead in exceedance of the Reference Area UPLs. The highest concentrations of these metals in soil (greater than 5 times the UPLs) were detected throughout the spent sandblast grit disposal area, the equipment laydown area, surrounding CB-1, within the area of erodible soils, and at two locations along the southeastern roadway. The locations with the highest concentrations (greater than 50 times the UPL) of chromium and lead were located along the northern area of the spent sandblast grit disposal area (HA6 through HA8; chromium and others for lead) and in the northern equipment laydown area (HA3), respectively.

Due to the elevated toxicity ratios for chromium, lead, and B2EHP, which are potentially bioaccumulative and the fact that several locations had concentrations greater than the SLVs, further investigation of these CPECs is recommended in the form of either a Level III BERA or remediation of the locations with elevated locations described above. In a Level III BERA to evaluate exposure to chromium, lead, and B2EHP in soil by birds, the following site-specific factors should be considered:

1. As previously described in the Sandblast Area AOPC risk interpretation, the approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls. However, these special-status species are not likely to forage at the 3.1 acre Sandblast Area AOPC and protection of terrestrial bird species at the population-level would be emphasized in the BERA for the Upland OU.

2. The site-specific Reference UPLs were greater than the risk-based soil SLVs (EcoSSLs) for chromium and lead and, therefore, the SLVs were replaced by the UPLs in the screening evaluation. In addition to evaluating specific bird target species and using literature-based BAFs to estimate dose, the contribution of background levels of metals would also be considered to better understand site-related dose contribution.
3. The size of the Sandblast Area AOPC relative to the size of a birds' home range would be factored into the daily dose estimation.

Mammals - Four metals (antimony, cadmium, chromium, and lead), dibenzofuran, and total HPAHs had toxicity ratios greater than 5.0 and were assessed for their potential to elicit adverse effects in mammal populations at the Sandblast Area AOPC. As shown in Tables 8-1, L-1 and L-2, all of the HPAHs were detected at concentrations statistically higher than the Reference Area data.

Figure 12-14 shows a sample by sample comparison to SLVs for the following CPECs that remain for mammals: antimony, cadmium, chromium, lead, dibenzofuran, and total HPAHs. Several locations had concentrations of these CPECs in exceedance of the mammal SLVs. The highest concentrations of these CPECs in soil (greater than 10 times the SLVs) were detected along the roadway in the southern portion of the AOPC, in the northeastern portion of the equipment laydown area, within the spent sandblast disposal area, in the erodible soils north of the former sandblast building, and around CB-1.

Due to the elevated toxicity ratios for antimony, cadmium, chromium, lead, and total HPAHs (Table N-14), which are potentially bioaccumulative with the exception of antimony, and the fact that several locations have concentrations greater than the SLVs (EcoSSLs that account for bioaccumulation), further investigation of these CPECs is recommended in the form of a Level III BERA or remediation of the locations with elevated concentrations. Antimony is not considered bioaccumulative (Table J-6) and therefore, would not be expected to be present in dietary tissues at levels of concern for mammals. However, due to the elevated toxicity ratios for this CPEC, which is based on the EcoSSL, additional evaluation is warranted. Studies have also demonstrated that PAHs are rapidly metabolized upon ingestion by birds and mammals, according to the USEPA EcoSSLs guidance document (2005a), and the potential for bioaccumulation in terrestrial habitats of PAHs is expected to be limited.

Dibenzofuran in soil does have potential to bioaccumulate, but little toxicity data exist to evaluate the consumption pathway for mammals precluding a meaningful Level III BERA for this CPEC. TRBs could not be found in USEPA or ORNL publications or databases, nor does USEPA's IRIS database provide an oral reference dose for dibenzofuran. As shown on Figure 12-14, dibenzofuran co-occurs with elevated detections of the other risk-driver CPECs at the northeastern portion of the equipment laydown area (cadmium, lead, and/or HPAHs), south of the current HMSA (HPAHs), and along the roadway in the southern portion of the AOPC (HPAHs). Since cadmium, lead, and HPAHs are recommended for further investigation and there is more confidence in the available data for these CPECs, lack of a site-specific evaluation of dibenzofuran is a manageable uncertainty for the Upland OU ERA. For these reasons, no further evaluation is recommended for dibenzofuran.

In a Level III BERA to evaluate exposure to antimony, cadmium, chromium, lead, and total HPAHs in soil by mammals, site-specific factors should be considered. In addition to evaluating specific mammal target species and using literature-based BAFs to estimate dose, the

contribution of background levels of metals would also be considered to better understand site-related dose contribution. Also, the size of the Sandblast Area AOPC relative to the size of a mammals' home range would be factored into the daily dose estimation.

Aquatic Organisms and Aquatic-Dependent Wildlife - Only one COI, cis-1,2-DCE, has a toxicity ratio greater than 1.0 and was assessed for its potential to elicit adverse effects in individual aquatic organisms or wildlife that could be exposed to surface water that has been impacted by COIs in groundwater from the Sandblast Area AOPC. However, based on the low toxicity ratio for cis-1,2-DCE (1.12; Table N-15), that it is not expected to bioaccumulate (log Kow < 3.5, Table J-6), and the fact that the wells immediately down gradient and adjacent to the river have concentrations below the SLV (Figure 12-15), no further evaluation is recommended for cis-1,2-DCE and no further investigation of groundwater at the Sandblast Area AOPC is recommended for protection of aquatic biota.

12.3.4.3.3 Pistol Range AOPC

Terrestrial Plants - Lead and zinc had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the plant community at the Pistol Range AOPC. Lead was detected in all soil samples (63 total from 0 to 1.5 feet bgs) at concentrations ranging from 7.5 to 1,100 mg/kg (Table I-3). Zinc was detected in all soil samples (10 total from 0 to 1.5 feet bgs) at concentrations ranging from 74 to 199 mg/kg (Table I-3). Based on the low toxicity ratio for zinc (1.24), high confidence in the SLV (USEPA EcoSSL), the fact that zinc is an essential nutrient, and the absence of protected species of terrestrial plants, no further evaluation is recommended for zinc.

Figure 12-16 shows a sample by sample comparison of lead concentrations to plant SLVs. The highest concentrations of lead, including the maximum concentration, were detected at and behind the backstop. Lead concentrations in this area of the site range between 5 and 10 times the SLV. The toxicity ratio for lead based on the maximum concentration is 9.25 (Table N-21), and when the 95% UCL (365 mg/kg) or mean (208 mg/kg) lead concentrations are used the toxicity ratio drops to 3.04 and 1.73, respectively.

Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation, with no special status plant species. A meadow covers the firing range, and the hillside behind the backstop is densely vegetated with herbaceous vegetation and shrub/forest fringe communities.

Based on the assessment for plants at the Pistol Range AOPC, it is possible that very localized impacts could occur from exposure to lead, although no visible signs of distress have been observed in the areas with highest lead concentrations. Potential effects to the terrestrial plant community are likely overestimated due to the assumption that these organisms are exposed to the maximum concentration of each CPEC throughout their life span. In addition, the studies upon which terrestrial plant SLVs were derived typically use crops as the test species, and sensitivity levels of undomesticated plant species are likely to be different than crops species. Based on these considerations, adverse effects to the terrestrial plant community at the Pistol Range are not expected to occur. However, lead is recommended for further investigation if a Level III BERA is performed because it was identified as a CPEC for other receptors at the Sandblast Area AOPC as well as plants..

Soil Invertebrates - Zinc has a toxicity ratio greater than 1.0 and was assessed for its potential to elicit adverse effects in the soil invertebrate community at the Pistol Range AOPC. Zinc was detected in all soil samples (10 total from 0 to 1.5 feet bgs) at concentrations ranging from 74 to 199 mg/kg (Table I-3). Based on the low toxicity ratio for zinc (1.66), high confidence in the SLV (USEPA EcoSSL), the fact that zinc is an essential nutrient, and the absence of protected species of soil invertebrates, no further evaluation is recommended for zinc.

Birds - Lead and zinc had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in individual birds at the Pistol Range AOPC. Of these two CPECs, only lead had a toxicity ratio greater than 5.0 and was assessed for potential impacts to bird populations. Figure 12-16 shows a sample by sample comparison to the SLVs for lead and zinc for birds. The toxicity ratios for lead and zinc were calculated using the Reference Area UPL as the SLV because the USEPA EcoSSLs for these metals are below the site-specific UPLs.

As shown on Figure 12-16, six locations near the former firing shed had zinc concentrations ranging between 1 to 5 times the SLV/UPL. The toxicity ratio for zinc was 2.06 (Table N-23). As stated previously in the Landfill AOPC risk interpretation, there are no protected species of terrestrial birds at the site. Based on the low toxicity ratio for zinc, absence of protected species of terrestrial birds, and because zinc is an essential nutrient for birds (metabolically regulated), no further evaluation is recommended for zinc.

The toxicity ratio for lead was 14.3 (Table N-23), and the highest concentrations of lead were detected at and behind the backstop. Although the majority of lead concentrations were between 1 to 5 times the SLV, lead concentrations were between 5 and 10 times the SLV at five locations around the former firing shed and between 10 and 50 times the SLV at nine locations around the backstop and at two locations around the former firing shed. Due to the elevated toxicity ratio for lead, which is potentially bioaccumulative, and the fact that several locations have concentrations greater than the SLV, further investigation of this CPECs is recommended in the form of either a Level III BERA or remediation of the locations with elevated locations described above. In a Level III BERA to evaluate exposure to lead in soil by birds, the following site-specific factors should be considered.

1. As previously described in the Landfill AOPC risk interpretation, the approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls; however, these special-status species are not likely to forage at the 0.26-acre Pistol Range AOPC and protection of terrestrial bird species at the population-level would be emphasized in the BERA for the Upland OU.
2. The site-specific Reference UPL was greater than the risk-based soil SLV (EcoSSL) for lead and, therefore, the SLV was replaced by the UPL in the screening evaluation. In addition to evaluating specific bird target species and using literature-based BAFs to estimate dose, the contribution of background levels of lead would also be considered to better understand site-related dose contribution.
3. The small size of the Pistol Range AOPC and the size of a birds' home range would be factored into the daily dose estimation.
4. A qualitative evaluation of the potential bioavailability of lead originating from the former firing range activities (i.e., lead shot) would be performed.

Mammals - Only lead had a toxicity ratio greater than 5.0 and was assessed for its potential to elicit adverse effects in mammal populations at the Pistol Range AOPC. The toxicity ratio for lead was 6.52 (Table N-24), and the highest concentrations of lead were detected at and behind the backstop. Lead concentrations were between 10 and 50 times the SLV at six locations around the backstop and at one location on the eastern corner of the former firing shed. Two other locations near the backstop had lead concentrations between 5 and 10 times the SLV. Lead was elevated above the SLV/UPL in 14 of the 63 soil samples collected. Due to the elevated toxicity ratio for lead, which is potentially bioaccumulative, and the fact that several locations have concentrations greater than the SLV, further investigation of this CPEC is recommended in the form of either a Level III BERA or remediation of the locations with elevated locations described above.

In a Level III BERA to evaluate exposure to lead in soil by mammals, site-specific factors should be considered. In addition to evaluating specific mammal target species and using literature-based BAFs to estimate dose, the contribution of background levels of metals would also be considered to better understand site-related dose contribution. Also, the size of the Pistol Range AOPC and the size of a mammals' home range would be factored into the daily dose estimation.

Aquatic Organisms and Aquatic-Dependent Wildlife - Although no CPECs were identified for the aquatic organisms potentially exposed to groundwater at the Pistol Range AOPC (based on their toxicity ratios all less than 1.0), zinc, a bioaccumulative COI, was retained as a CPEC due to the lack of a dietary-based SLV.

Benthic Invertebrates - Zinc has a toxicity ratio slightly greater than 1.0 (1.41), and the maximum concentration of zinc in lagoon sediment (174 mg/kg; Table I-14) was higher than the concentration detected in random Forebay sediment samples (113 mg/kg; Table I-18a). However, the low toxicity ratio for zinc detected in lagoon sediment and lack of special status benthic invertebrate species suggests a low potential for risk to the benthic community in the lagoon from exposure to zinc.

As mentioned previously, sediment samples from the lagoon were collected to determine if any COIs that could have originated from the former Pistol Range AOPC should be added to the list of COIs evaluated for the River OU. Zinc was assessed for its potential to elicit adverse effects in the benthic invertebrate community in the ERA for the River OU through an evaluation of zinc detected in sediment of the River (Section 12.5). Protection of the benthic community in the River is discussed in that section of the ERA.

Fish and Aquatic-Dependent Wildlife - The maximum detected concentrations of lead and zinc in lagoon sediment were greater than the Reference Area UPLs, which were used in the absence of sediment SLVs that are protective of fish and wildlife. Maximum concentrations of lead and zinc in lagoon sediment (33 and 174 mg/kg, respectively; Table I-14) were higher than concentrations detected in random Forebay sediment samples (16.8 and 113 mg/kg, respectively; Table I-18a). However, these metals were evaluated for their potential to bioaccumulate in the ERA for the River OU through an evaluation of these metals in detected in site tissue samples (Section 12.5), and the protection of fish and aquatic-dependent wildlife is discussed in that section of the ERA.

12.3.4.3.4 Bulb Slope AOPC

Terrestrial Plants – Lead and mercury had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in the plant community at the Bulb Slope AOPC. Lead was detected in all soil samples (12 total from 0 to 1-foot bgs) at concentrations ranging from 25 to 597 mg/kg (Table I-4). Mercury was also detected in all soil samples (12 total from 0 to 1-foot bgs) at concentrations ranging from 0.05 to 1.54 mg/kg (Table I-4). The topography is steep and the substrate at the Bulb Slope AOPC consists of a mixture of soils, rock that may have been placed in some areas, and what appear to be natural rock outcrops, all of which is underlain by siltstone bedrock. The majority of the Bulb Slope AOPC is herbaceously vegetated and/or covered with organic debris.

Figure 12-17 shows a sample by sample comparison of soil concentrations to the plant SLV for lead and mercury. The toxicity ratio for lead based on the maximum concentration was 4.98 (Table N-35), and when the 95% UCL of 307 mg/kg or mean of 222 mg/kg lead concentrations at 0 to 1 foot (Table I-15) are used the toxicity ratio dropped to 2.6 and 1.85, respectively. Nine samples had concentrations in exceedance of the SLV, and no samples have concentrations in exceedance of 5 times the SLV.

The toxicity ratio for mercury based on the maximum concentration was 5.13 (Table N-35), and when the 95% UCL of 0.72 mg/kg or mean of 0.4 mg/kg mercury concentrations (Table I-15) are used the toxicity ratio dropped to 2.4 and 1.35, respectively. Six samples had concentrations in exceedance of the SLV (between the SLV and 5 times the SLV), and only one of these six samples (Pile #3 Bank #4) had a concentration between 5 and 10 times the SLV (Figure 12-17).

Given the relatively low exceedances of the plant SLVs for lead and mercury and lack of special status plant species at the Bulb Slope AOPC, the potential for adverse effects to the terrestrial plant community is expected to be limited. However, these CPECs are recommended for further investigation in a Level III BERA because they were identified as CPECs for other receptors at the Bulb Slope Area AOPC as well as plants.

Soil Invertebrates - Mercury had a toxicity ratio greater than 1.0 and was assessed for its potential to elicit adverse effects in the invertebrate community at the Bulb Slope AOPC. As stated above, mercury was detected in all soil samples, with concentrations ranging from 0.05 to 1.54 mg/kg.

Figure 12-17 shows a sample by sample comparison of soil concentrations to the invertebrate SLV for mercury. Nine soil samples had concentrations in exceedance of the SLV, and three of these nine samples had concentrations higher than 5 times the SLV (one of these also exceeded ten times the SLV). The toxicity ratio for mercury based on the maximum concentration was 15.4 (Table N-36), and when the 95% UCL (0.72 mg/kg) or mean (0.4 mg/kg) mercury concentrations (Table I-15) were used the toxicity ratio dropped to 7.2 and 4.0, respectively.

Based on the number of exceedances of the soil invertebrate SLVs for mercury and elevated toxicity ratios, further investigation of this CPEC is recommended in the form of either a Level III BERA or remediation of the locations with elevated locations.

Birds - Lead and mercury had toxicity ratios greater than 1.0 and were assessed for their potential to elicit adverse effects in birds at the Bulb Slope AOPC. Figure 12-17 shows a sample by sample comparison of soil concentrations to the avian SLVs for lead and mercury. The toxicity ratios for lead and mercury were calculated using the Reference Area UPL as the SLV

because the USEPA EcoSSLs for these metals are below the site-specific UPLs. The toxicity ratios for lead and mercury were 12.0 and 10.9, respectively (Table N-37).

As shown on Figure 12-17, lead and mercury concentrations at most locations (9 of 12) exceeded the UPLs/SLVs. Of these nine samples, five locations had concentrations between 5 and 10 times the SLV and four locations had concentrations between 10 and 50 times the SLV for one or both of these CPECs. Due to the elevated toxicity ratios for lead and mercury, which are potentially bioaccumulative, and the fact that several locations had concentrations greater than the SLV, further investigation of these CPECs is recommended in the form of either a Level III BERA or remediation of the locations with elevated locations described above. In a Level III BERA to evaluate exposure to lead and mercury in soil by birds, the following site-specific factors should be considered.

1. As previously described in the Landfill AOPC risk interpretation, the approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls; however, these special-status species are not likely to forage at the 0.05-acre Bulb Slope AOPC and protection of terrestrial bird species at the population-level would be emphasized in the BERA for the Upland OU.
2. The site-specific Reference UPL was greater than the risk-based soil SLV (EcoSSL) for lead and mercury and, therefore, the SLVs were replaced by the UPLs in the screening evaluation. In addition to evaluating specific bird target species and using literature-based BAFs to estimate dose, the contribution of background levels of these CPECs would also be considered to better understand site-related dose contribution.
3. The small size of the Bulb Slope AOPC and the size of a birds' home range would be factored into the daily dose estimation.

Mammals - Lead had a toxicity ratio greater than 5.0 and was assessed for its potential to elicit adverse effects in mammal populations at the Bulb Slope AOPC. Figure 12-17 shows a sample by sample comparison of soil concentrations to the mammalian SLV for lead. Two soil samples had concentrations between 5 and 10 times the SLV, and one sample had a lead concentration between 10 and 50 times the SLV. The toxicity ratio for lead was only slightly above 5.0 (5.48) (Table N-38).

The topography is steep and the substrate at the Bulb Slope AOPC consists of a mixture of soils, rock that may have been placed in some areas, and what appear to be natural rock outcrops, all of which is underlain by siltstone bedrock. Access to this area would be challenging for larger mammals, given the steep slope and rocks. Based on the low magnitude of the toxicity ratio for lead, lack of special status mammals, and in consideration of small size of this rocky area, adverse effects to mammal populations at the site are not expected to occur. However, lead is recommended for further investigation in a Level III BERA because it has been identified as CPEC for other receptors at the Bulb Slope as well as mammals.

12.3.4.3.5 All Four AOPCs Combined

Tables N-43 and N-44 present the results of the screening for individual COIs evaluated for birds and mammals, respectively, that potentially have home ranges equal to or larger than the size of the entire Upland OU and could, therefore, forage over all four AOPCs. Tables N-45 and N-46 provide the results of the toxicity-based screening analysis that involved an evaluation of the

cumulative risks associated with simultaneous exposure to multiple COIs present in a given medium.

A comparison of the soil CPECs identified for the four AOPCs combined versus those identified for the individual AOPCs was performed to determine if any discrepancies exist in this lists of CPECs. No additional CPECs for birds and mammals were identified for the combined AOPCs dataset that were not already identified for the individual AOPC datasets. To address exposures for birds and mammals that could forage over all four AOPCs, the CPECs identified through the individual AOPC screening evaluations should also be assessed for exposures to all four AOPCs by birds and mammals, as appropriate, in a Level III BERA.

12.3.5 Summary of Level II Screening Assessment for Upland OU

Table 12-1 summarizes the CPECs identified through the Level II Screening Assessment that are recommended for risk management, which could entail further investigation or focused remediation.

In addition to the receptors and CPECs listed in Table 12-1 for the Upland AOPCs, the bioaccumulative CPECs at the Landfill and Sandblast Area AOPCs for which dietary-based SLVs are not available (Tables N-3, N-4, N-13, and N-14) also warrant further consideration for birds and mammals. If a Level III BERA is performed, a first critical step would be to determine which bioaccumulative CPECs have corresponding TRVs, as the absence of TRVs for these CPECs could preclude a full quantitative evaluation. At a minimum, all bioaccumulative CPECs would be discussed qualitatively. Finally, risk management is recommended to address the potential erosional soils at the Landfill, Sandblast Area, and Bulb Slope AOPCs that could be mobilized and transported to the River OU if erosion/mass wasting were to occur (e.g., localized soil removal, erosion control measures).

As discussed in Section 8.2.1, to address the uncertainty with the results of the statistical background comparison, metals with high MDDs were subjected to a risk-based screening evaluation in Appendix O. The purpose of this evaluation is to explore whether or not these metals should be included as COPCs, and ultimately advanced to the next level of risk assessment or directly to the FS. A weight-of-evidence approach similar to the one implemented in Section 12 was used to evaluate these metals, as described in Appendix O.

12.4 Level I Scoping Assessment For River OU

The general tasks involved in a Level I Scoping Assessment summarized in Section 12.1.1 for the Upland OU also apply to the River OU. The main goal of the Level I evaluation is to determine if complete exposure pathways potentially exist at a site, and if a Level II Screening Assessment should be performed. To fulfill the requirements of a Scoping Assessment, the ecological setting, site features (topography, structures), nature and extent of all known chemical releases, current and future uses of land and water, and any unique site-specific characteristics described in previous sections were carefully considered. The identification of COIs and CPECs described for the Upland OU in Section 12.2.1 is equivalent to the process used for the River OU.

12.4.1 COIs in River Media

The physical environment of the River OU is much more dynamic than the Upland OU. As discussed previously, the electrical equipment and debris and the majority of the contaminated sediment have been removed from the river, and water movement and human activities have redistributed sediment within the Forebay. In Section 6.2, recent site investigations are described in detail, and the COIs in River media are identified.

In order to focus on the current river conditions and the identification of current COIs, only analytical results from investigations in the River OU since 2007 are included in the RI River OU data set and used in the ERA, with the exception of smallmouth bass collected in 2006. Based on the presence of potentially complete exposure pathways and associated analytical data, COIs in the River OU were identified for the following media: sediment, surface water, and fish and benthic invertebrate tissue.

The categories of COIs that were identified in the recent River OU and 2006 Forebay smallmouth bass analytical data include metals, PCBs, TPH, and SVOCs including PAHs. Of these COIs, a subset is considered to be bioaccumulative in aquatic environments, as presented in Section 7.3 and Table J-7. The screening tables described in Section 12.5.4.1 and presented in Appendix N provide the potentially bioaccumulative COIs detected in the random Forebay, Goose Island, and Eagle Creek sediment data sets. The tissue data collected from the Forebay (including Goose Island) were emphasized in the identification of truly bioaccumulative COIs for this project.

12.4.2 Ecological Exposure Pathways

Sediment and water are sources for uptake of bioaccumulative chemicals by benthic and aquatic organisms, which are consumed by upper trophic level receptors. The following potential exposure pathways are identified for the River OU, and these pathways were more thoroughly investigated to identify those that warrant a quantitative evaluation in the Level II Screening Assessment (Section 12.5.2.1):

- Uptake of contaminants potentially present in surface water by aquatic organisms (plants, aquatic invertebrates, and fish)
- Ingestion of and dermal contact with contaminants potentially present in sediment and surface water by benthic invertebrates
- Incidental ingestion of and dermal contact with potentially contaminated surface water and sediment by aquatic-dependent wildlife (dermal contact is expected to be minor due to the barriers offered by fur and feathers)
- Ingestion of benthic and aquatic dietary components (e.g., invertebrates and fish) by upper trophic level receptors (fish and wildlife)

The exposure pathways that are complete at the River OU and their associated receptors were quantitatively evaluated in the Level II Screening Assessment.

12.5 Level II Screening Assessment For River OU

This section describes the methodology and findings of Level II Screening Assessment for the River OU.

The comprehensive description of the nature and extent of COIs in the River OU is provided in Section 9.6. In Sections 9.1.2, the first two steps of the CPEC selection process (evaluation of detection frequency and comparison to background levels for inorganics) were performed for all media associated with the Forebay, Goose Island, and Eagle Creek (Tables 9-9 to 9-11).

The two targeted sediment sample locations placed on the eastern bank of the mouth of Eagle Creek were collected to evaluate potential exposure by recreational waders, and these samples are also included as a targeted dataset in this ecological Level II Screening Assessment. The two targeted sample locations placed in the slough on the southern side of Goose Island, where sediment, clams, crayfish, and sculpin were collected at the request of DEQ, were also included in the screening.

12.5.1 Receptors of Interest

A simplified food-web model for the River OU is presented on Figure 12-18. Discussion regarding the selection of aquatic receptors of interest (or "target receptors") occurred in several meetings during 2005 and early 2006 with the TAG for Bradford Island. The following terrestrial receptors of interest were selected in the RI/FS MP (URS 2007a):

- Benthic invertebrates represented by the clam (*Corbicula fluminea*) and crayfish (*Pacifastus spp.*)
- Aquatic plants and water-column invertebrates
- Resident fish represented by the sculpin (*Cottus spp.*) and smallmouth bass (*Micropterus dolomieu*) (Although salmonids are known to be particularly sensitive to exposure to PAHs and PCBs (Meador 2000; Johnson et al 2000), evaluation of the resident species is expected to be protective of anadromous and transient species due to their higher level of site use at all life stages.)
- Osprey (*Pandion haliaetus)*
- Bald eagle
- Mink

In the Level II Screening Assessment, these organisms are evaluated as receptor groups (aquatic plants and invertebrates, benthic invertebrates, fish, and piscivorous birds and mammals) through a comparison to generic SLVs for each group. During a Level III BERA, the specific receptors listed above, which represent the feeding guilds present in the River OU, would be assessed for exposure and risk.

Although considered to be semiaquatic and highly reliant upon the riverine environment for resources, the bald eagle and the mink may both frequent the uplands, where they would likely supplement their primarily aquatic diet with upland prey items, such as small mammals. In the event that unacceptable risks are demonstrated for piscivorous birds and mammals from exposure to media of the River OU, more realistic assumptions that incorporate refinements to their dietary compositions may be considered if a Level III BERA is warranted.

12.5.2 Exposure Assessment

Exposure assessment is the process of estimating the magnitude, frequency, and duration of site-specific exposure concentrations of chemicals to a receptor. To assess whether COI concentrations at the site have the potential to cause adverse effects in the selected ecological receptors, it is first necessary to develop reasonable estimates of the concentrations to which the receptors might be exposed.

12.5.2.1 Conceptual Exposure Model for Ecological Receptors

A CEM for ecological receptors of the River OU is presented on Figure 12-19. This CEM focuses on potentially complete pathways associated with the Forebay, which are also applicable to Goose Island Slough and Mouth of Eagle Creek. The aquatic-related exposure pathways identified for the River OU in Section 12.4.2 are reflected in the CEM :

- Uptake of contaminants potentially present in surface water by aquatic organisms
- Ingestion of and dermal contact with contaminants potentially present in sediment and surface water by benthic invertebrates, fish, and wildlife (dermal contact is expected to be minor for aquatic-dependent wildlife due to the barriers offered by fur and feathers)
- Ingestion of benthic and aquatic dietary components (e.g., invertebrates and fish) by piscivorous fish and wildlife

These pathways are potentially complete for the River OU and were quantitatively evaluated.

12.5.2.2 Assessment Endpoints

The recommended assessment endpoints for the ecological receptors addressed in the River OU are listed below.

- Protection of aquatic biota (invertebrates and fish) that may be exposed to COIs in sediment or surface water or from Upland OU sources (e.g., groundwater or soil washoff).
- Protection of piscivorous mammals, such as the mink, against unacceptable effects on reproduction, growth, or development at the population level due to COIs in sediment, invertebrates, water, and aquatic food.
- Protection of top-level predatory birds, such as the American bald eagle and osprey, against unacceptable effects on reproduction, growth, or development at the population level due to COIs in sediment, water, and aquatic food.

Protection on an individual basis was the focus for state- or federally listed threatened and endangered species (i.e., bald eagle, salmon) that may occur from exposure to media of the River and/or Upland OUs.

12.5.2.3 Estimation of Exposure Point Concentrations

For plankton, aquatic plants and invertebrates, fish, and benthic invertebrates, the EPC is estimated as a function of the COI concentration measured in water, sediment, or tissue. For piscivorous birds and mammals, the exposure dose may be estimated as a function of the COI concentration in relevant environmental media and several other parameters related to biological transfer through the food web and the manner in which receptors use the site.

All samples collected from the River were analyzed for both PCB congeners (all 209 congeners) and Aroclors, volume permitting. Therefore, EPCs in abiotic and biotic media collected from the site may be calculated for the following PCB groupings:

- Individual Aroclors
- Total PCBs as the sum of Aroclors
- Total PCBs as sum of 209 congeners
- 2,3,7,8-TCDD TEQs for the 12 dioxin-like PCB congeners

Aquatic Organisms (plankton, aquatic plants, pelagic invertebrates, and fish) and Aquatic-Dependent Wildlife - For the Level II Screening Assessment, EPCs in flowing surface water are represented by the maximum concentration detected in the five surface water samples.

Benthic Invertebrates - The maximum detected concentration was selected as the EPC for sediment, clam, and crayfish data evaluated to assess risk to the benthic community (as represented by these two organisms). Use of the maximum concentration of each COI is a conservative approach that serves to protect sessile organisms that could conceivably be exposed to the maximum concentration throughout their entire life span.

Piscivorous Birds, Mammals, and Fish - For food web-based receptors such as birds, mammals, and piscivorous fish, the EPC was based on the 95% UCL on the mean concentration in sediment and tissue. The lower of the 95% UCL and maximum detected concentration was ultimately used as the EPC for these receptors. This value provides an estimate of the representative concentration more relevant to terrestrial wildlife receptors that generally are mobile and not continuously exposed to site-related COIs in one geographic location.

As presented in the RI/FS MP (URS 2007a), site-specific bird and mammals target receptors that would be evaluated if a Level III BERA is warranted for the River OU include bald eagle, osprey, and mink. The tissue sampling performed in the River between 2008 and 2009 to support the RI was designed with a specific aquatic food web model in mind and the following assumptions regarding dietary intake by these target receptors:

- Bald eagle and osprey consume 100% smallmouth bass (i.e., Level 3-4 fish)
- Mink consumes 33% crayfish (benthic invertebrates), 33% sculpin (Level 2-3 fish), and 33% smallmouth bass

The bald eagle and osprey would not likely consume significant amounts of smaller fish (e.g., sculpin) and invertebrates (e.g., crayfish) in the River OU, and the assumption that they solely consume top predatory fish, like smallmouth bass, is expected to result in worst-case exposure to bioaccumulative and biomagnifying COIs. However, for purposes of this Level II Screening Assessment, aquatic-dependent birds as a general category were assumed to feed on crayfish, sculpin, and bass.

Although a specific target fish species was not selected, several species were identified that could inhabit the Forebay in Table C-4 of the RI/FS MP (URS 2007a). These fish species occupy various feeding guilds in the food web and, therefore, it was assumed that all types of tissue collected (clams, crayfish, sculpin, and bass) could be consumed by fish as a generic receptor group. The single sample of sucker was considered too small of a sample size to be included in the tissue dataset. However, the data from the sucker were evaluated relative to the bass tissue

concentrations and tissue SLVs protective of fish (i.e., critical tissue levels [CTLs]) and wildlife (i.e., ATLs) in the uncertainty analysis (Appendix O).

12.5.3 Effects Analysis

A brief introduction to the Effects Analysis phase of the ERA was provided for the Upland OU (Section 12.3.3). The same process was applied to the River OU.

12.5.3.1 Measurement Endpoints

As discussed in Section 12.3.3.1, the measures of exposure and measures of effect proposed for the assessment endpoints were provided in Table C-1 of the RI/FS MP (URS 2007a). Measurement endpoints for the River ERA primarily include measured EPCs in sediment, tissue, and surface water collected from the Forebay. No modeling of sediment or water to tissue was necessary, as site-specific COI concentrations in two types of benthic invertebrates (clams and crayfish) and two types of fish (sculpin and smallmouth bass) were compared directly to tissue SLVs protective of these receptors groups, as well as to SLVs protective of upper-trophic-level receptors that may consume these organisms.

12.5.3.2 Direct Toxicity and Bioaccumulation SLVs

The EPCs for sediment, water, and tissue were compared to the SLVs protective of the individual receptor groups of interest evaluated for the River OU (e.g., aquatic plants and invertebrates, benthic invertebrates, fish, and piscivorous birds and mammals). The primary literature sources of SLVs protective of ecological receptors that were used in the Level II Screening Assessment were presented in Section 7.3 and Appendix J.

The tissue SLVs were compared to the types of tissue that correspond to the dietary intake assumptions described in Section 12.5.2.3:

1. SLVs protective of fish/shellfish were compared to all tissue data
2. SLVs protective of birds were compared to crayfish, sculpin, and smallmouth bass tissue data (as three distinct datasets; no combination of tissues indicating dietary proportions were performed for this Screening Assessment)
3. SLVs protective of mammals were compared to crayfish, sculpin, and smallmouth bass data (as three distinct datasets; no combination of tissues indicating dietary proportions were performed for this Screening Assessment)

The following section describes the methods used to screen the site data against these SLVs for the identification of CPECs.

12.5.3.3 Identification of Chemicals of Potential Ecological Concern

The first two steps of the CPEC identification process presented in Section 12.2.1 (i.e., evaluation detection frequency and comparison to Reference Area concentrations for inorganics) were considered for the random and target Forebay data sets in Section 9.1. River OU COIs that were detected in ≤ 5% of samples per media could potentially be eliminated as CPECs, as long as there were at least 20 samples collected. However, because none of the River OU media had at least 20 samples no COIs were removed from CPEC evaluation based on detection frequency (Tables 9-9 through 9-11).

For the second step, a comparison of two independent data sets for each media was performed between the Reference Area sediment and tissues (clam, crayfish, smallmouth bass, and sculpin) and the random Forebay sediment and tissues, including the 2006 smallmouth bass tissue. The objective of the statistical analysis was to assess whether the mean inorganic COI concentrations in the random Forebay post-removal sediment and tissues were significantly higher than the mean Reference Area sediment and tissue concentrations. This approach is commonly known as a population-to-population comparison. The results of this statistical comparison are presented in detail in Section 8.0 and Appendix L and summarized in Table 8-3.

Since the comparisons for between Forebay and Reference Area surface water only evaluated total concentrations, and the screening level ERA uses dissolved concentrations, no inorganic compounds were eliminated based on comparison to Reference Area concentrations. All detected metals were screened against surface water SLVs.

The following summarizes the inorganic COIs in sediment and tissue at the Forebay (random) with significantly higher concentrations than the Reference Area (Tables 8-3):

- Sediment – None.
- Clam – Beryllium and cadmium.
- Crayfish – Antimony, arsenic, chromium, mercury, methyl mercury, and nickel.
- Sculpin – Cadmium, lead, and mercury.
- Smallmouth bass – Aluminum, barium, copper, mercury, and zinc.

For the targeted Forebay sampling locations at Goose Island Slough and the mouth of Eagle Creek, which do not have enough samples to perform a statistical (population-to-population) comparison, the maximum detected inorganic concentrations in sediment and tissue (clam and crayfish) were compared to the inorganic 95% UPLs in the Reference Area. The following summarizes the inorganic COIs in sediment and tissue at Goose Island and Eagle Creek with maximum detected concentrations greater than the Reference Area 95% UPLs (Table L-7).

- Eagle Creek Sediment – None.
- Goose Island Sediment – Antimony, cadmium, thallium, and zinc.
- Goose Island Clam – Beryllium.
- Goose Island Crayfish – Mercury.

The inorganic COIs in sediment and tissue at the Forebay (random and targeted) that were found to not be elevated above the Reference Area were not retained as CPECs.

All detected organic COIs and all inorganic COIs with concentrations above Reference Area levels were retained for the third step of the CPEC identification process, i.e., toxicity-based screening. The approach used for the screening to evaluate direct toxicity for benthic invertebrates (exposed to sediment) and aquatic organisms (exposed to surface water) is the same as the approach described in Section 12.3.3.3 for the Upland OU (i.e., toxicity ratios for individual COIs and multiple COIs).

The potential for bioaccumulation and the availability of SLVs are two additional qualitative elements that were evaluated in the identification of CPECs. Bioaccumulation potential of COIs

in sediment was assessed using the methods presented in Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (DEQ 2007). COIs detected in sediment and tissue were screened against DEQ's bioaccumulation SLVs (including ATLs and CTLs) for freshwater fish and shellfish, bird, mammal populations by creating bioaccumulation indices, calculated using the following equation:

$$R_{BAC} = \frac{EPC}{Bioaccumulation\ SLV}$$

where :

R_{BAC} = bioaccumulation index for chemical

EPC = Exposure point concentration

Bioaccumulation SLV = DEQ's Bioaccumulation SLV (2007)

In general, bioaccumulation indices less than 1 indicate sediment or tissue concentrations at which adverse environmental effects are not expected to occur. Any individual bioaccumulative COI in a given medium with $R_{BAC} > 0.1$, and for which the sum $R_{BAC} > 1$ for a given medium (i.e., addition of all R_{BAC}s for that medium), was identified as a CPEC to account for both exposures to individual COIs, as well as simultaneous exposure to all COIs.

The tissue data were the primary line of evidence to select CPECs for the fish and benthic invertebrate consumption pathway for predatory fish and wildlife. Given the uncertainties regarding chemical transfer, uptake, and accumulation in organisms that are ingested by predators inherent to sediment bioaccumulation SLVs, site-specific tissue data are always a better representation of EPCs that receptors would encounter at a site. For this reason, all COIs in tissue were evaluated in the Screening Assessment, and then the list of CPECs in tissue was carried to the sediment data evaluation. The list of CPECs in tissue comprises the list of COIs which were evaluated in sediment, and this analysis will assist with risk management decisions for the River OU based on the two possible outcomes:

- If a CPEC in tissue is also present in sediment at concentrations in exceedance of the bioaccumulation SLV (i.e., it is also a CPEC in sediment), then further risk assessment may be helpful to evaluate the actual potential for adverse effects to occur from exposure to site-related CPEC concentrations.
- If a CPEC in tissue is undetected in sediment, present below Reference Area levels (inorganics only), or present at concentrations below sediment SLVs, further risk assessment may not be helpful because tissue concentrations likely do not correlate with current sediment concentrations at the site. If this is the case, the tissue levels could reflect exposure to other sources in the river or could reflect historical body burdens. Risk management or some level of monitoring may be warranted for certain tissue CPECs that are not found to be CPECs in sediment.

Since the objective of collecting the samples at the mouth of Eagle Creek was to assess exposure by people wading, no tissue data were collected from that area. Therefore, the potentially bioaccumulative COIs in these samples were compared to the bioaccumulation SLVs for sediment.

12.5.4 Risk Characterization

A brief introduction to the Risk Characterization phase of the ERA was provided for the Upland OU (Section 12.3.4). The same process was applied to the River OU.

12.5.4.1 Results of Toxicity Screening

The toxicity screening for COIs in sediment, tissue, and surface water of the River OU involved a comparison of appropriate EPCs to corresponding media-specific SLVs protective of the receptor groups evaluated in this Level II Screening Assessment. The potential for ecological risk to occur was evaluated based on exposure to individual COIs within a specific medium and from exposure to multiple COIs simultaneously within a given medium.

Toxicity ratios for benthic invertebrates exposed directly to sediment and aquatic organisms exposed to surface water were estimated for each COI, as described in Section 12.5.3.3. If the toxicity ratio (T_{ij}) for a specific COI is greater than the receptor designator (Q) appropriate for the site, or if the toxicity ratio for a specific COI is a high contributor to the total risk for a given medium (summation of all toxicity ratios), then further investigation of the COI is warranted and it was retained as a CPEC. As defined by DEQ (2001), Q is equal to 1.0 for all benthic and aquatic organisms exposed to sediment and surface water.

Any individual bioaccumulative COI in a given medium with $R_{BAC} > 0.1$, and for which the sum $R_{BAC} > 1$ for a given medium, was identified as a CPEC. The bioaccumulation SLVs protective of individuals of listed threatened and endangered wildlife species (birds and mammals) and SLVs protective of populations of these receptors groups were applied in the screening comparison.

The results of the screening are presented for the Random Forebay, Goose Island, and Eagle Creek in the following sections.

12.5.4.1.1 Random Forebay Data

Tables N-47 through N-50 of Appendix N present the results of the screening for individual COIs in Forebay sediments and surface water, and simultaneous exposure to multiple COIs, to evaluate direct toxicity to benthic invertebrates and aquatic organisms. Tables N-51, N-53, N-54, N-57, and N-58 present the results of the screening for COIs in tissue to evaluate the dietary exposure pathway for predatory fish and shellfish (and other aquatic organisms) and aquatic-dependent wildlife at both the individual and population levels. Tables N-52, N-55, N-56, N-59, and N-60 present the results of the screening for COIs in sediment to evaluate the dietary exposure pathway and essentially assess the potential current site contribution to tissue levels. As discussed in Section 12.5.3.3, the information gathered through the comparison of tissue CPECs and sediment CPECs was used to guide recommendations for the next steps of the site investigation process, including the utility of future risk assessment.

Benthic Invertebrates

Direct Toxicity Evaluation - Only Aroclor 1254 was identified for the benthic invertebrate community in the Forebay based on the individual COI screening evaluation for sediment (Table N-47). Maximum concentrations of total PCBs as the sum of all Aroclors and as the sum of all congeners were below the corresponding SLVs. Aroclor 1254 also contributes to a cumulative risk greater than 1.0 (Table N-48) and requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in the benthic community.

DRO and RRO were retained as CPECs in sediment due to the lack of SLVs protective of benthic invertebrates. The implications to the findings of the Screening Assessment are discussed in the uncertainty assessment (Appendix O).

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which were based on a comparison of measured clam and crayfish concentrations from the site to tissue SLVs protective of fish and shellfish.

Aquatic Organisms and Aquatic-Dependent Wildlife

Direct Contact Evaluation - Barium was the only CPEC identified for the aquatic receptors in the Forebay based on the individual and multiple COI screening evaluations for surface water (Tables N-49 and N-50). Barium requires further investigation in the risk interpretation section to assess its potential to elicit adverse effects in aquatic receptors.

DRO were retained as CPECs in surface water due to the lack of SLVs protective of aquatic organisms and wildlife. The implications to the findings of the Screening Assessment are discussed in the uncertainty assessment (Appendix O).

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which were based on a comparison of measured clam and crayfish concentrations from the site to tissue SLVs protective of fish and shellfish. Likewise, the findings of the evaluation for birds and mammals were based on a comparison of measured sculpin, crayfish, or bass concentrations from the site to tissue SLVs protective of birds and mammals (Section 12.5.3.2).

Fish and Shellfish

Tissue. Table N-51 presents the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for each type of organism collected in the Forebay. The tissue SLVs (i.e., DEQ's CTLs) are protective of upper trophic level fish and shellfish in and of themselves and, therefore, were screened against the Forebay clam, crayfish, sculpin, and smallmouth bass data. Cadmium, PCBs (as total congeners only), and B2EHP were identified as CPECs in clam tissue. There were no CPECs identified for crayfish due to exceedance of tissue SLVs. Cadmium, lead, mercury, and PCBs (Aroclor 1254, total Aroclors, total PCB congeners, three of 12 dioxin-like congeners, and PCB TEQ for Fish [i.e., Fish TEQ]) were identified as CPECs in sculpin tissue. Mercury, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, five of 12 dioxin-like congeners, and Fish TEQ), B2EHP, and butyl benzyl phthalate were identified as CPECs in smallmouth bass tissue. All of these CPECs require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in upper trophic level fish and shellfish that consume these tissues. In addition, beryllium and p-cresol (4-Methylphenol) in clam tissue, antimony, chromium, and nickel in crayfish tissue, and aluminum, barium, copper, and zinc in bass tissue were retained as CPECs due to the lack of SLVs for tissue.

Sediment. Of the CPECs listed above for the various tissue types, only PCBs (Aroclor 1254 and total Aroclors) were also identified as CPECs in sediment (Table N-52). B2EHP was detected in sediment and was retained as a CPEC due to the lack of a sediment SLV that addresses the dietary pathway. The results of the population to population statistical comparisons demonstrated that the metals detected in tissue above Reference Area concentrations were not present in the Forebay sediment at concentrations above Reference Area sediment concentrations (Tables L-4 and N-52). Therefore, it is difficult to assess the site contribution of the metal CPECs in site sediment to the Forebay tissue levels. Due to this difficulty, all CPECs in sediment (and tissue) were carried to the risk interpretation section.

Piscivorous Birds

Tissue. Tables N-53 and N-54 present the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for crayfish, sculpin, and smallmouth tissue collected in the Forebay that could be consumed by piscivorous birds (such as bald eagles and osprey) known to occur in the vicinity of Bradford Island. Table N-53 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-54 shows the results of the population level assessment.

The tissue SLVs (or DEQ's ATLs) are protective of piscivorous birds that could forage in the Forebay. Mercury, methyl mercury and total PCB congeners were identified as CPECs in crayfish tissue. Mercury and PCBs (Aroclor 1254, total Aroclors, total PCB congeners, five of the 12 dioxin-like congeners, and PCB TEQ for birds [i.e., Avian TEQ]) were identified as CPECs in sculpin tissue. Mercury, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, seven dioxin-like congeners, and Avian TEQ), and di-n-butyl phthalate were identified as CPECs in smallmouth bass tissue. All of these CPECs require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered birds. Mercury and most of the PCBs listed above also require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in bird populations (Table N-54).

In addition, antimony, chromium, and nickel in crayfish tissue and aluminum, barium, copper, and zinc in bass tissue were retained as CPECs due to the lack of SLVs for tissue. PAHs were also retained as tissue CPECs due to the lack of tissue SLVs for birds, and the implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O.

Sediment. Of the CPECs listed above in the various tissue types, PCBs (Aroclor 1254, total Aroclors, total PCB congeners, and one dioxin-like congener) were also identified as CPECs in sediment and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered birds (Table N-55). None of these CPECs were found in sediment at concentrations that could cause adverse effects in piscivorous bird populations (Table N-56).The results of the population to population statistical comparisons demonstrated that metals detected in tissue above Reference Area concentrations were not present in the Forebay sediment at concentrations above Reference Area sediment concentrations (Tables L-4, N-55, and N-56).Therefore, it is difficult to assess the site contribution of the metal CPECs in site sediment to the Forebay tissue levels. Due to this, all CPECs in sediment (and tissue) were carried to the risk interpretation section.

Piscivorous Mammals

Tissue. Tables N-57 and N-58 present the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for crayfish, sculpin, and smallmouth tissue collected in the Forebay that could be consumed by piscivorous mammals (such as mink) that are known to occur in the vicinity of Bradford Island. Table N-57 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-58 shows the results of the population level assessment.

The tissue SLVs (or DEQ's ATLs) are protective of piscivorous (and invertivorous) mammals that could forage in the Forebay. With the exception of CPECs retained due to lack of SLVs, only PCBs (three dioxin-like congeners and the PCB TEQ for mammals [i.e., Mammalian TEQ]) are CPECs for crayfish tissue. Mercury and PCBs (Aroclors 1254, total Aroclors, total PCB congeners, eight of the 12 dioxin-like congeners, and Mammalian TEQ) are CPECs in sculpin tissue. Mercury and PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, ten dioxin-like congeners, and Mammalian TEQ) were identified as CPECs in smallmouth bass tissue. All of these tissue CPECs require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered mammals. Mercury and most of the PCBs listed above also require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in mammal populations.

In addition, antimony, chromium, and nickel in crayfish tissue and aluminum, barium, copper, and zinc in bass tissue were retained as CPECs due to the lack of SLVs for tissue.

Sediment. Of the CPECs listed above in the various tissue types, PCBs (four dioxin-like congeners and the Mammalian TEQ) were also identified as CPECs in sediment and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected mammals (Tables N-59). No CPECs were found in sediment at concentrations that could cause adverse effects in piscivorous mammal populations (Table N-60). The results of the population to population statistical comparisons demonstrated that metals detected in tissue above Reference Area concentrations were not present in the Forebay sediment at concentrations above Reference Area sediment concentrations (Tables L-4, N-57, and N-58). Therefore, it is difficult to assess the site contribution of the metal CPECs in site sediment to the Forebay tissue levels. Due to this, all CPECs in sediment (and tissue) were carried to the risk interpretation section.

12.5.4.1.2 Mouth of Eagle Creek

Tables N-61 and N-62 of Appendix N present the results of the screening for individual COIs in sediments collected from the mouth of Eagle Creek (two samples), and simultaneous exposure to multiple COIs, to evaluate direct toxicity to benthic invertebrates. Tables N-63 through N-67 present the results of the screening for bioaccumulative COIs in sediment to evaluate the dietary exposure pathway for predatory fish and shellfish and aquatic-dependent wildlife at both the individual and population levels. Since the objective of collecting the samples from Eagle Creek was to assess the direct contact pathway for waders in the HHRA (URS 2007a), no tissue samples were collected from this area. The sediment samples were analyzed for PCBs as Aroclors, in addition to metals, SVOCs (PAHs), and TPH. No PCB congener data were collected.

Because tissue data have been collected from the greater Forebay (the random samples), the purpose of the bioaccumulation evaluation for Eagle Creek sediment was to identify any

additional CPECs that have not already been identified through the random Forebay sampling event. Any bioaccumulative CPECs identified in Eagle Creek sediments (i.e., maximum sediment concentration above the bioaccumulation SLV) were compared to the tissue data to determine their actual presence in measured tissue data from the Forebay.

Benthic Invertebrates

Direct Toxicity Evaluation – PCBs (Aroclor 1248 and total Aroclors) were the only CPECs identified for the benthic community at the mouth of Eagle Creek based on the individual and multiple COI screening evaluations for sediment (Tables N-61 and N-62). PCBs require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in the benthic community.

DRO were retained as CPECs in sediment due to the lack of SLVs protective of benthic invertebrates, and the implications of these uncertainties to the findings of the Screening Assessment are discussed in the uncertainty assessment (Appendix O).

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which are based on a comparison of bioaccumulative COI concentrations in sediment to sediment SLVs protective of fish and shellfish.

Fish and Shellfish

Table N-63 presents the bioaccumulative CPECs with a sediment $R_{BAC} > 0.1$ and sum sediment $R_{BAC} > 1.0$ that could pose a health risk to upper trophic level fish and shellfish. PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above the bioaccumulative SLV protective of fish and shellfish. These CPECs require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in upper trophic level fish and shellfish.

Carbazole and DRO were retained as CPECs in sediment due to the lack of a bioaccumulation SLV protective of fish and shellfish, and the implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O. Of these two CPECs, only carbazole was identified as potentially bioaccumulative in aquatic environments based on the criteria discussed in Section 7.3 (Table J-7).

Aroclor 1248 was not detected in the random Forebay sediment samples (it was only detected in one sample at Eagle Creek). Instead, Aroclor 1254 is the primary PCB mixture detected in random sediment and tissue samples. Aroclor 1254 and total PCBs as Aroclors are bioaccumulative CPECs in Forebay sediment, crayfish, and smallmouth bass for which the Screening Assessment indicates the potential for adverse effects in upper trophic level fish and shellfish that consume these tissues and are exposed to CPECs in sediment.

Piscivorous Birds

Tables N-64 and N-65 present the bioaccumulative CPECs with a sediment $R_{BAC} > 0.1$ and sum sediment $R_{BAC} > 1.0$ that could pose a health risk to piscivorous birds (such as bald eagles and osprey) known to occur in the vicinity of Bradford Island. Table N-64 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-65 shows the results of the population level assessment.

PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above the bioaccumulative SLV protective of birds, and require further investigation in the risk

interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered birds. Except for potential CPECs that were retained due to lack of SLVs, no CPECs were identified that could elicit adverse effects in bird populations.

Carbazole, PAHs, and DRO were retained as CPECs in sediment due to the lack of a bioaccumulation SLVs protective of birds, and the implications of these uncertainties to the findings of the Screening Assessment are discussed in Appendix O. Of these CPECs, carbazole and PAHs were identified as potentially bioaccumulative in aquatic environments based on the criteria discussed in Section 7.3 (Table J-7).

As stated above, Aroclor 1248 was not detected the random Forebay sediment samples (it was only detected in one sample at Eagle Creek). Instead, Aroclor 1254 is the primary PCB mixture detected in random sediment and tissue samples.

Piscivorous Mammals

Tables N-66 and N-67 present the bioaccumulative CPECs with a sediment $R_{BAC} > 0.1$ and sum sediment $R_{BAC} > 1.0$ that could pose a health risk to piscivorous mammals (such as mink) that are known to occur in the vicinity of Bradford Island. Table N-66 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-67 shows the results of the population level assessment.

PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above the bioaccumulative SLV protective of mammals, and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered mammals. Except for potential CPECs that were retained due to lack of SLVs, no CPECs were identified that could elicit adverse effects in mammal populations.

Carbazole and DRO were retained as CPECs in sediment due to the lack of a bioaccumulation SLV protective of mammals, and the implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O. Of these two CPECs, only carbazole was identified as potentially bioaccumulative in aquatic environments based on the criteria discussed in Section 7.3 (Table J-7).

As stated above, Aroclor 1248 was not detected in the random Forebay sediment samples (it was only detected in one sample at Eagle Creek). Instead, Aroclor 1254 is the primary PCB mixture detected in random sediment and tissue samples.

12.5.4.1.3 Goose Island Slough

Tables N-68 through N-69 of Appendix N present the results of the screening for individual COIs in Goose Island sediment samples, and simultaneous exposure to multiple COIs, to evaluate direct toxicity to benthic invertebrates. No surface water data have been collected at Goose Island. Tables N-70 and N-71 presents the results of the screening for COIs in tissue and sediment to evaluate the dietary exposure pathway for predatory fish and shellfish. Tables N-72 through N-75 present the results of the screening for COIs in tissue and sediment to evaluate dietary exposure to aquatic-dependent birds at both the individual and population levels. Tables N-76 through N-79 present the results of the screening for COIs in tissue and sediment to evaluate the dietary exposure pathway and essentially assess the potential current site contribution to tissue levels for aquatic-dependent mammals. As discussed in Section 12.5.3.3, the information gathered through the comparison of tissue CPECs and sediment CPECs will be

used to guide recommendations for the next steps of the site investigation process, including the utility of future risk assessment.

Many of the smallmouth bass collected in 2006 were from the Goose Island slough. These samples were collected as part of the random Forebay sampling effort and are, therefore, presented under the Random Forebay Data discussion above. Since bass are one of the primary food source for piscivorous birds and mammals and predatory fish that could forage at the Forebay, including Goose Island, a summary of the screening results for bass tissue collected from the Forebay is provided below for these three receptor groups.

Benthic Invertebrates

Direct Toxicity Evaluation - Cadmium, thallium, zinc, and Aroclor 1254 were identified for the benthic invertebrate community in the Goose Island slough based on the individual and cumulative COI screening evaluations for sediment (Tables N-68 and N-69) and require further investigation in the risk interpretation section to assess its potential to elicit adverse effects in the benthic community.

DRO and RRO were retained as CPECs in sediment due to the lack of SLVs protective of benthic invertebrates, and the implications of these uncertainties to the findings of the Screening Assessment are discussed in Appendix O.

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which are based on a comparison of measured clam and crayfish concentrations from the site to tissue SLVs protective of fish and shellfish.

Fish and Shellfish

Tissue. Table N-70 presents the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for clams, crayfish, and sculpin collected from Goose Island. The tissue SLVs (or DEQ's CTLs) are protective of upper trophic level fish and shellfish in and of themselves and, therefore, were screened against these tissue data. No CPECs were identified in these targeted tissue samples from Goose Island, with the exception of beryllium and p-cresol (4-methylphenol), which were detected in clam tissue, due to the absence of tissue SLVs. As shown in Table N-51 and previously discussed in Section 12.5.4.1.1, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, five of 12 dioxin-like congeners, and Fish TEQ), B2EHP, and butyl benzyl phthalate are CPECs in randomly-collected smallmouth bass tissue samples from the Forebay. Of the metals identified as tissue CPECs, a tissue SLV was only available for mercury. The EPC for mercury in randomly-collected bass tissue exceeded the tissue SLV; however, the EPC for mercury in crayfish tissue collected from the targeted locations at Goose Island is below the tissue SLV.

Sediment. Of the random Forebay smallmouth bass tissue organic CPECs, PCBs (Aroclor 1254 and total Aroclors) are also CPECs in Goose Island sediment (Table N-71). P-cresol (4-methylphenol), which was detected in Goose Island clam tissue but lacked a tissue SLV, was also detected in sediment and was retained as a sediment CPEC due to the lack of a sediment SLV that addresses the dietary pathway. In addition, B2EHP was detected in Goose Island sediment (but not in Goose Island clams, crayfish, and sculpin) and was retained as a CPEC due to the lack of a SLV that addresses the dietary pathway.

Of the metals identified above as tissue CPECs in Goose Island clam tissue and random Forebay bass tissue, zinc was also identified as a Goose Island sediment CPEC due to SLV exceedance

(Table N-71). The results of the Reference Area comparison demonstrated that all the remaining metals identified above were present in the targeted Goose Island sediment samples at concentrations similar to or less than Reference Area sediment concentrations (Tables L-7 and N-71). Therefore, it is difficult to assess the contribution of the metal CPECs in Goose Island sediment to the Forebay bass tissue levels, with the possible exception of zinc. Due to this difficulty, all CPECs in Goose Island sediment (and tissue) were carried to the risk interpretation section.

Piscivorous Birds

Tissue. Tables N-72 and N-73 present the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for crayfish and sculpin tissue collected at Goose Island that could be consumed by piscivorous birds. Table N-72 shows the results of the bioaccumulation screening to assess potential adverse effects in birds at the individual level; Table N-73 shows the results of the population level assessment. The tissue SLVs (or DEQ's ATLs) are protective of piscivorous birds that could forage in the Forebay, including Goose Island.

No CPECs were identified in crayfish or sculpin tissue collected from Goose Island, with the exception of those without SLVs (i.e., PAHs.). As shown in Tables N-53 and N-54 and previously discussed in Section 12.5.4.1.1, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, seven dioxin-like congeners, and Avian TEQ), di-n-butyl phthalate, and PAHs were identified as CPECs in the randomly-collected smallmouth bass tissue collected from the Forebay.

PAHs were retained as tissue CPECs due to the lack of SLVs for birds. The implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O.

Sediment. Tables N-74 and N-75 present the bioaccumulative CPECs in targeted Goose Island sediment samples with $R_{BAC} > 0.1$ and sum sediment $R_{BAC} > 1.0$. Table N-74 shows the results of the bioaccumulation screening to assess potential adverse effects in birds at the individual level; Table N-75 shows the results of the population level assessment. Of the CPECs listed above in smallmouth bass, zinc, PCBs (Aroclor 1254, total Aroclors, total PCB congeners, one dioxin-like congener, and Avian TEQ) were also identified as CPECs in sediment and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered birds. Zinc and PCBs (Aroclor 1254 and total Aroclors) were detected in sediment at levels that could elicit adverse effects in piscivorous bird populations (Table N-75). It is worth noting that the sediment SLV for zinc is represented by the Reference Area UPL (i.e., not a risk-based SLV). In addition, di-n-butyl phthalate and PAHs were retained as CPECs in sediment due to the lack of SLVs protective of birds.

Of the metals identified above as tissue CPECs in random Forebay bass tissue, the results of the Reference Area sediment comparison demonstrated that all but zinc were present in the targeted Goose Island sediment samples at concentrations similar to or less than Reference Area sediment concentrations (Tables L-7, N-74, and N-75). Therefore, it is difficult to assess the contribution of the metal CPECs in Goose Island sediment to the Forebay tissue levels, with the possible exception of zinc. Due to this, all CPECs in Goose Island sediment (and tissue) were carried to the risk interpretation section.

Piscivorous Mammals

Tissue. Tables N-76 and N-77 present the bioaccumulative CPECs with a tissue $R_{BAC} > 0.1$ and sum tissue $R_{BAC} > 1.0$ for clams, crayfish, and sculpin collected from Goose Island that could be consumed by piscivorous mammals. Table N-76 shows the results of the bioaccumulation screening to assess potential adverse effects in mammals at the individual level; Table N-77 shows the results of the population level assessment. No CPECs were identified in the targeted tissue samples from Goose Island at either the individual or population level. As shown in Tables N-57 and N-58 and previously discussed in Section 12.5.4.1.1, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, ten of 12 dioxin-like congeners, and Mammalian TEQ) were identified as CPECs in randomly-collected smallmouth bass tissue samples from the Forebay that could be consumed by piscivorous mammals.

Sediment. Tables N-78 and N-79 present the bioaccumulative CPECs in targeted Goose Island sediment samples with $R_{BAC} > 0.1$ and sum sediment $R_{BAC} > 1.0$ at the individual and population level, respectively, for aquatic-dependent mammals. Of the CPECs identified for smallmouth bass, zinc and PCBs (Aroclor 1254 and total Aroclors) were also identified as CPECs in sediment and require further investigation in the risk interpretation section to assess their potential to elicit adverse effects in individual protected threatened and endangered mammals, as well as in mammal populations. It is worth noting that the sediment SLV for zinc is represented by the Reference Area UPL (i.e., not a risk-based SLV).

Of the metals identified above as tissue CPECs in random Forebay bass tissue, the results of the Reference Area sediment comparison demonstrated that all but zinc were present in the targeted Goose Island sediment samples at concentrations similar to or less than Reference Area sediment concentrations (Tables L-7, N-78, and N-79). Therefore, it is difficult to assess the contribution of the metal CPECs in Goose Island sediment to the Forebay tissue levels, with the possible exception of zinc. Due to this, all CPECs in Goose Island sediment (and tissue) were carried to the risk interpretation section.

12.5.4.2 Uncertainty Assessment

A brief introduction to the Uncertainty Assessment phase of the ERA was provided for the Upland OU (Section 12.3.4.2), which also applies to the River OU. Specific sources of uncertainty for this Level II ERA are presented in Appendix O.

12.5.4.3 Risk Interpretation

In this final phase of the risk characterization process, the quantitative and qualitative components of the risk screening (i.e., toxicity ratios and R_{BACs}) and the uncertainty assessment are evaluated to gain a better understanding of the actual potential for ecological risk. Multiple lines of evidence are considered during risk interpretation to identify actual risk drivers at the site and to develop a supportable recommendation for risk managers to review. The outcome of the risk characterization constitutes the basis of remedial decisions for the protection of ecological receptors and risk-driving exposure pathways.

For the screening to evaluate direct toxicity to benthic and aquatic receptors through exposure to sediment and surface water, the CPECs with toxicity ratios greater than 1.0 for benthic invertebrates and aquatic biota are retained for further investigation in this section. For the bioaccumulation screening to evaluate the dietary exposure pathway for fish and wildlife, the CPECs with a $R_{BAC} > 0.1$ and sum $R_{BAC} > 1.0$ are further investigated in this section.

The summary of the risk screening process described in Section 12.3.4.3 for the Upland OU, whereby SLVs were compared to 95% UCLs (mobile receptors) and maximum concentrations (stationary receptors) and a whittled down list of CPECs was identified to plot on figures to evaluate spatial distribution, also applies to the approach used for the River OU. Based on this weight of evidence approach, those CPECs that truly warrant additional investigation or risk management were identified and discussed.

Since evaluation of the tissue data was the preferred method to identify tissue CPECs for predatory fish and wildlife, all COIs in tissue were evaluated in the Screening Assessment, and then the list of CPECs in tissue was carried to the sediment data evaluation. The results of this phased screening process for tissue followed by sediment will assist with risk management decisions for the River OU based on the two possible outcomes previously presented (Section 12.5.3.3):

- If a CPEC in tissue is also present in sediment at concentrations in exceedance of the bioaccumulation SLV (i.e., it is also a CPEC in sediment), then further risk assessment may be helpful to evaluate the actual potential for adverse effects to occur from exposure to site-related CPEC concentrations.
- If a CPEC in tissue is either undetected, present below Reference Area concentrations (inorganics only), or present below sediment SLVs, further risk assessment may not be helpful because tissue concentrations likely do not correlate with current sediment concentrations at the site. If this is the case, the tissue levels could reflect exposure to other sources in the river or could reflect historical body burdens. Risk management or some level of monitoring may be warranted for certain tissue CPECs that are not found to be CPECs in sediment.

Those CPECs for which a limited number of exceedances were noted (e.g., Aroclor 1248 for benthic invertebrates in Eagle Creek) were generally not included on the spatial distribution maps, but were still discussed using a similar weight-of-evidence approach as the remaining CPECs. The CPECs identified in Section 12.5.4.1 for the Forebay (both random and targeted sample areas) and associated receptors are discussed below.

12.5.4.3.1 Random Forebay Data

Benthic Invertebrates

Direct Toxicity Evaluation - Only Aroclor 1254 was identified for the benthic invertebrate community in the Forebay based on the individual and cumulative COI risk screening evaluations for sediment (Tables N-47 and 48) and was assessed for its potential to elicit adverse effects in the benthic community. Maximum concentrations of total PCBs as the sum of all Aroclors and as the sum of all congeners were below the corresponding SLVs.

Aroclor 1254 was detected in two of 19 randomly-collected sediment samples (detection frequency of 11%), and exceeded the SLV in one of these samples (location P4 on the north side of Bradford Island, Figure 12-20). The toxicity ratio calculated using the maximum detected concentration of Aroclor 1254 was 3.86 (Table N-47), and decreases to 0.826 if the K-M mean concentration was used as the EPC (the maximum concentration was selected as the 95% UCL given the large number of non-detects) (Table I-18a). The elevated toxicity ratio for Aroclor 1254 indicates the potential for localized impacts (at P4) to benthic invertebrates. Given the low detection frequency for Aroclor 1254 in sediment and low toxicity ratios based on the maximum

and mean concentrations, adverse effects to the benthic invertebrate community at the Forebay are not expected to occur. However, PCBs (including Aroclor 1254) are recommended for further investigation because they been identified as CPECs for other receptors in the River as well as benthic invertebrates.

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below for a comparison of measured clam and crayfish concentrations from the site to tissue SLVs protective of fish and shellfish.

Aquatic Organisms and Aquatic-Dependent Wildlife

Direct Contact Evaluation - Barium was the only CPEC identified for the aquatic receptors in the Forebay based on the individual and multiple COI screening evaluations for surface water (Tables N-49 and N-50) and was assessed for its potential to elicit adverse effects in aquatic receptors.

Barium was detected above the surface water SLV in all five Forebay filtered surface water samples as well as the five filtered surface water samples collected from the Reference Area. Dissolved barium concentrations in surface water in the Forebay ranged from 0.021 to 0.024 mg/L (Table 6-12c) and concentrations in the Reference Area ranged from 0.0215 to 0.0235 mg/L (Table 6-12d). The toxicity ratio for barium in surface water was 6.0 (Table N-49). Given the very similar concentrations of barium detected in Forebay and Reference Area surface water samples, and the relatively low toxicity ratio that is based on a Tier II Secondary Chronic Value (DEQ 2001), no further evaluation is recommended for aquatic receptors exposed through direct contact with Forebay surface water.

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below for a comparison of measured sculpin and bass concentrations from the site to tissue SLVs protective of fish and shellfish. Likewise, the findings of the evaluation for birds and mammals are based on a comparison of measured sculpin, crayfish, or bass concentrations from the site to tissue SLVs protective of birds and mammals (Section 12.5.3.2).

Fish and Shellfish

Tissue SLVs protective of upper trophic level fish and shellfish were screened against the Forebay clam, crayfish, sculpin, and smallmouth bass data. Table N-80 summarizes the CPECs for fish and shellfish based on a comparison to SLVs that were identified in the various tissues randomly collected from the Forebay (Table N-51). The CPECs shown with an asterisk on Table N-80 were also identified as CPECs in Forebay sediment (Table N-52).

As described in Section 12.5.4.1, EPCs for cadmium, lead, and mercury exceeded the tissue SLVs. Eight other metals were detected in Forebay tissues and retained as CPECs due to the lack of tissue SLVs. However, the results of the population to population statistical comparisons demonstrated that none of these metals were present in Forebay sediment at concentrations above Reference Area sediment concentrations (Table L-4). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels. Although none of these metals are CPECs in sediment, those that are present above the tissue SLVs (cadmium, lead, and mercury) are recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

In addition, p-cresol (4-methylphenol) was detected in the Forebay in six of 19 sediment samples (at concentrations ranging from 4.8 to 21 µg/kg) and ten of 19 clam samples (at

concentrations ranging from 8.6 to 31 µg/kg). It was retained as a CPEC due to the lack of SLVs for sediment and tissue. p-Cresol was not detected in Forebay crayfish (15 samples) or smallmouth bass (19 samples). Furthermore, the concentrations detected in Forebay sediment and clam tissue were not statistically higher than the concentrations detected in the Reference Area for any of the media (Table 8-3). Based on the low concentrations of p-cresol detected in Forebay sediment and clams in comparison to the Reference Area, and the low bioaccumulation potential for p-cresol (log K_{ow} = 1.94; Table J-7), which is supported by the absence this CPEC in sculpin, crayfish, and bass, lack of a quantitative risk-based screening for p-cresol is not expected to influence the findings of the ERA. No further investigation of p-cresol is recommended.

Figure 12-20 shows a sample by sample comparison of CPEC concentrations to SLVs for the protection of upper trophic level fish and shellfish. Tissue concentrations are shown for cadmium, lead, mercury, PCBs, and the two phthalates. Sediment concentrations are shown for PCBs, which was the only sediment CPEC identified due to exceedance of its SLV (Table N-52). For simplicity, due to the higher level of confidence in PCB analytical data reported as congeners for weathered or metabolized PCBs, and due to the consistently higher risk estimates of total PCBs as congeners in tissue, only the PCB congener totals are presented on Figure 12-20. Additionally, B2EHP was identified as a CPEC due to lack of an SLV and potential to bioaccumulate (not shown on Figure 12-20).

Clams

The clam tissue R_{BACs} (i.e., EPC divided by bioaccumulation SLV) for cadmium, total PCB congeners, and B2EHP were 2.55, 0.298, and 0.407, respectively. The population to population comparison for clam tissue found that cadmium was present in the Forebay at concentrations above those measured in Reference Area clam tissue. Cadmium concentrations in clam tissue were between 1 and 10 times the SLV in all random samples collected from the Forebay (Figure 12-20). However, the cadmium concentration ranges were similar (0.286 and 0.461 mg/kg in the Forebay [Table 6-9a] and between 0.247 and 0.405 mg/kg in the Reference Area [Table 6-9b]; see Figure L-3a). Given the low R_{BACs} calculated with clam tissue from the Forebay, absence of CPECs in crayfish tissue, and similarity in cadmium concentration ranges in Forebay and Reference Area clams and sediment, there is a low potential for adverse effects to the benthic community from exposure through the dietary pathway.

Sculpin

The sculpin tissue R_{BACs} for cadmium, lead, and mercury were 0.162, 0.858, and 2.13, respectively (Table N-51). The sculpin tissue R_{BACs} for PCBs ranged from 0.186 (PCB 156+157) to 7.40 (total PCBs as congeners). For simplicity and due to the higher level of confidence in PCB analytical data reported as congeners for weathered or metabolized PCBs, total PCBs as congeners was used to represent all PCB CPECs on the figures. The tissue R_{BAC} for the Fish TEQ of 0.668 is much lower than the tissue R_{BAC} for total PCBs as congeners (7.40). The Fish TEQ SLV for tissue (0.0064 µg/kg) is only exceeded at SF-3, i.e., the location with the maximum concentration of total PCBs as congeners in sculpin tissue. The two other locations with the highest PCBs levels in sculpin tissue have concentrations in exceedance of 0.1 times the SLV for the Fish TEQ (SF-4 and SF-5). .

As stated previously, total PCBs as congeners was used to represent all PCB CPECs on Figure 12-20. The highest concentrations of PCBs in sculpin tissue occurred at SF-3, SF-4, and SF-5, on

the southeastern tip of the island, and these are the only three samples that exceed the SLV (but are less than 10 times the SLV). Co-located PCB sediment concentrations in this area were less than 0.1 times the SLV, and clam concentrations were between 0.1 and 1 times the SLV. Cadmium, mercury, and to a lesser extent, lead, concentrations were between 0.1 and 10 times the SLV in several sculpin samples collected throughout the Forebay, and did not appear attributable to site sediment concentrations (the Forebay sediment data were not statistically higher than the Reference Area data) (Table L-4).

Since cadmium, mercury, and lead concentrations in sculpin tissue were comparable throughout the Forebay (R_{BACs} are relatively low), and sediment concentrations of these metals were no different from the Reference Area (Table L-4), further risk assessment is unlikely to be helpful for these metals. Tissue concentrations likely do not correlate with current sediment concentrations in the Forebay. Based on the elevated sculpin tissue concentrations throughout the Forebay, it is likely that other sources (besides sediment concentrations) influence the cadmium, lead, and mercury concentrations measured in the sculpin. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway.

Risk management or monitoring is recommended for PCBs, and possibly cadmium, lead, and mercury, in sculpin tissue to protect predatory fish that may be exposed through their diet. The size of a sculpin's home range (1.61 km) is greater than the distance between the SF-3, SF-4, and SF-5 cluster, and sediment station P4 (approximately 0.36 km). Therefore, it is possible for the sculpin in these areas to have foraged in the vicinity of P4, where sediment concentrations of PCBs were between 1 and 10 times the SLV and clam concentrations were between 0.1 and 1 times the SLV. However, the implications of this localized exceedance of the sediment SLV in terms of current site contributions to concentrations of PCBs in sculpin tissue are unknown. It is likely that the sculpin tissue levels reflect historical body burdens, influences from upstream sources, or a combination of the two.

Smallmouth Bass

The smallmouth bass tissue R_{BACs} for mercury, B2EHP, and butylbenzyl phthalate were 3.60, 0.192, and 0.771, respectively (Table N-51). The bass tissue R_{BACs} for PCBs ranged from 0.153 (PCB 114) to 44.9 (total PCBs as congeners). The tissue R_{BAC} for the Fish TEQ of 4.58 is much lower than the tissue R_{BAC} for total PCBs as congeners (44.9), and the Fish TEQ SLV for tissue (0.0064 μg/kg) is only exceeded at bass locations 11 and 17, i.e., the locations with the maximum concentrations of total PCBs as congeners. The six remaining locations that exceed 0.1 times the SLV for the Fish TEQ (2, 3, 8, 13, 16 and 18) also exceed either 0.1 times the SLV or the whole SLV for total PCBs as congeners.

As stated previously, total PCBs as congeners was used to represent all PCB CPECs on Figure 12-20. The highest concentrations of PCBs in bass tissue occurred at location 17, on northeastern tip of the island, and location 11 in the Goose Island slough. Total PCB concentrations in bass at these locations exceed 10 times the SLV. Several other bass caught from locations had PCB concentrations between 0.1 and 10 times the SLV.

Mercury was also present in bass tissue at concentrations between 1 and 10 times the SLV. Although concentrations of mercury in Forebay bass were significantly higher than in the Reference Area (Table L-4), the concentration ranges in bass tissue were generally comparable between the Forebay (0.0710 – 0.512 mg/kg) (Table 6-6a) and the Reference Area (0.0548 –

0.333 mg/kg) (Table 6-6b). This is consistent with the fact that mercury concentrations in Forebay sediments were not significantly higher than those in the Reference Area (Table L-4).

B2EHP was detected between 0.1 and 1 times the SLV in two bass tissue samples (8 and 15) collected from the Goose Island slough, but did not have a sediment SLV for evaluation of the sediment samples (Figure 12-20). Butylbenzyl phthalate was detected at a concentration between 1 and 10 times the SLV in only one bass sample (16), and was undetected in all sediment samples (Figure 12-20).

The low detection frequency for B2EHP and butylbenzyl phthalate in Forebay bass tissue (37% and 11%, respectively, Table I-8a) and low concentrations detected supports the position that these compounds are readily metabolized and only weakly bioaccumulate (similar to the metabolic action noted in PAHs). At other contaminated sediment sites, including the Lower Duwamish Waterway, phthalates often occur with other compounds (e.g., PCBs) that drive risk. The phthalates are typically overshadowed by these more potent risk-drivers (Sediment Phthalate Work Group 2007). Given the low frequency of tissue SLV exceedances and low R_{BACs} for the phthalates, there is a low potential for adverse effects to fish from exposure through the dietary pathway. However, it is recommended that future investigations analyze for and evaluate all SVOCs.

Since mercury bass tissue concentrations were elevated throughout the Forebay, mercury bass tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful for mercury. Based on the ubiquitously elevated bass tissue levels for mercury in the River as a whole, it is likely that other sources influenced the concentrations measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway).

Risk management or monitoring is recommended for PCBs, and possibly mercury, in bass tissue to protect predatory fish that may be exposed through their diet. While it is possible for the bass to forage in the vicinity of P4, where the maximum sediment concentration of PCB was between 1 and 10 times the SLV and clam concentrations were between 0.1 and 1 times the SLV, this small area is unlikely to account for the PCB concentrations measured in bass tissue. Although the implications of this localized exceedance of the sediment SLV in terms of current site contribution to concentrations of PCBs and mercury in bass tissue are unknown, it is likely that the measured bass tissue concentrations reflect historical body burdens, influences from upstream sources, or a combination of the two.

Piscivorous Birds

The Forebay crayfish, sculpin, and smallmouth bass data were screened against tissue SLVs protective of piscivorous birds. Table N-81 summarizes the CPECs for piscivorous birds identified in crayfish and fish tissues based on a comparison to SLVs (Tables N-53 and Table N-54). The CPECs shown with an asterisk in Table N-81 were also identified as CPECs in Forebay sediment (Tables N-55). No population-level CPECs were identified for sediment.

As described in Section 12.5.4.1, EPCs for mercury exceeded the tissue SLVs. Seven other metals were detected in Forebay tissues and retained as CPECs due to the lack of tissue SLVs. However, the results of the population to population statistical comparisons demonstrated that none of these metals were present in the Forebay sediment at concentrations above Reference

Area sediment concentrations (Table L-4). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels.

Although none of these metals are CPECs in sediment, the one present above the tissue SLVs (mercury) is recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

Figure 12-21 shows a sample by sample comparison of CPEC concentrations to SLVs for the protection of piscivorous birds at the individual level. Tissue and sediment concentrations are shown for mercury, total PCBs as congeners, and Avian TEQs.

Crayfish

The crayfish tissue R_{BACs} for mercury at the avian individual and population levels were 0.320, and 0.158, respectively (Table N-53 and Table N-54). The crayfish tissue R_{BACs} for methyl mercury at the avian individual and population levels were very similar at 0.445, and 0.219, respectively. Only the crayfish tissue R_{BAC} for total PCBs as congeners was above 0.1 times the SLV at the individual level (R_{BAC} = 1.04). All other R_{BACs} for PCBs, including the Avian TEQ, are below 0.1 times the SLV protective of individual birds and, therefore, only total PCBs as congeners in crayfish tissue was identified as a CPEC.

As shown on Figure 12-21, the highest concentration of PCBs in crayfish tissue (between 1 and 10 times the SLV protective of individual birds) occurred at P6-CF on the southeastern tip of the island. PCB concentrations in crayfish from P4-CF, P5-CF, P7-CF, and P14-CF were between 0.1 and 1 times the SLVs protective of individual birds. PCBs detected in sediment were greater than 10 times the SLV for individual birds in one sample (P4), between the SLV and 10 times the SLV in one sample (P9), and between 0.1 times the SLV and the whole SLV in most of the remaining samples.

Mercury (and methyl mercury) concentrations in crayfish tissue were below the SLV protective of individual birds in all samples, and between 0.1 times the SLV and the whole SLV in all samples collected throughout the Forebay. Although concentrations of methyl mercury in Forebay crayfish were significantly higher than in the Reference Area (Table L-4), the concentration ranges in crayfish tissue were generally comparable between the Forebay (0.025 – 0.04 mg/kg) and the Reference Area (0.0181 – 0.0367 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediment were no higher than in Reference Area sediment (Table L-4 and N-55). Based on the low methyl mercury concentrations in crayfish, the potential for adverse effects in birds is expected to be low.

Risk management or monitoring is recommended for PCBs in crayfish tissue to protect piscivorous birds that may be exposed through their diet. The low R_{BACs} for crayfish tissue of 1.04 (Table N-53) and sediment of 1.99 (Table N-55) based on exposure by individual birds should be considered, as crayfish are not likely a driver species for birds (higher concentrations were detected in sculpin and bass tissue).

Sculpin

The sculpin tissue R_{BACs} for mercury at the avian individual and population levels were 2.53, and 1.25, respectively (Table N-53 and Table N-54). The sculpin tissue R_{BACs} greater than 0.1 times the SLVs for PCBs at the individual level ranged from 0.309 (PCB 126) to 90.9 (total PCBs as congeners), and at the population level ranged from 0.125 (PCB 118) to 1.77 (total PCBs as

congeners). The sculpin tissue R_{BACs} for the Avian TEQ at the individual and population levels were 1.59, and 0.754, respectively.

As shown on Figure 12-21, the highest concentrations of PCBs in sculpin tissue (greater than 10 times the SLV) occurred at SF-3, SF-4 and SF-5 on the southeastern tip of the island. PCB concentrations in sculpin from SF-2. SF-6, SF-12, SF-14, SF-16, and SF-17 were between the SLV and 10 times the SLV, and concentrations at the remaining locations are between 0.1 times the SLV and the whole SLV. The highest concentration of the Avian TEQ in sculpin tissue (between the SLV and 10 times the SLV) occurred at SF-3, and most of the remaining concentrations fall between 0.1 times the SLV and the whole SLV.

As indicated above, PCBs detected in sediment were greater than 10 times the SLV for individual birds in one sample (P4), between the SLV and 10 times the SLV in one sample(P9), and between 01 times the SLV and the whole SLV in most of the remaining samples. Sample P04 is the only location with an Avian TEQ concentration between 0.1 times the SLV and the whole SLV, all remaining sediment concentrations are below 0.1 times the SLV (Figure 12-21).

Mercury concentrations were between the SLV and 10 times the SLV in several sculpin samples collected throughout the Forebay. Although concentrations of mercury in sculpin were significantly higher than in the Reference Area (Table L-4), the concentration ranges in sculpin tissue were generally comparable between the Forebay (0.037 – 0.308 mg/kg) and the Reference Area (0.0448 – 0.141 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediment were no higher than in Reference Area sediment (Table L-4 and N-55).

Since mercury sculpin tissue concentrations were elevated throughout the Forebay (R_{BACs} were relatively low), mercury sculpin tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful. Based on the ubiquitously elevated bass tissue levels for mercury in the River as a whole, it is likely that other sources influenced the concentrations measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway).

Risk management or monitoring is recommended for PCBs, and possibly mercury, in sculpin tissue to protect piscivorous birds that may be exposed through their diet. However, the low sediment R_{BACs} for PCBs, and low concentrations detected in the sediment samples relative to the tissue data, do not indicate a current source of PCBs in the Forebay. It is likely that the sculpin tissue levels reflect historical body burdens, influences from upstream sources, or a combination of the two.

Smallmouth Bass

Di-n-butyl phthalate was detected in one of 19 bass tissue samples (Table I-8a) and was not detected in any other medium collected from the Forebay. It was not detected in Reference Area tissues, but was detected in Reference Area sediment (Table I-11). The R_{BAC} for di-n-butyl phthalate in bass tissue from the Forebay is 0.24 (Table N-53). Based on the absence of this compound from all but one Forebay tissue sample and low detection in this sample, no further investigation of di-n-butyl phthalate is recommended.

PAHs were retained as tissue CPECs due to the lack of tissue SLVs for birds, and the implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O.

Figure 12-21 shows a sample by sample comparison of CPEC concentrations to SLVs for the protection of birds. Tissue concentrations are shown for mercury and PCBs (total PCBs as congeners and Avian TEQs). Sediment concentrations are shown for PCBs (total PCBs as congeners and Avian TEQs), which were the only sediment CPECs identified (Table N-55), as well as mercury.

The smallmouth bass tissue R_{BACs} for mercury at the individual and population levels were 4.28, and 2.11, respectively (Tables N-53 and N-54). The bass tissue R_{BACs} for PCBs at the individual level ranged from 0.135 (PCB 167) to 552 (total PCBs as congeners), and at the population level ranged from 0.144 (Aroclor 1242) to 10.7 (total PCBs as congeners). The bass tissue R_{BACs} for the Avian TEQ at the individual and population levels were 36.4, and 17.3, respectively.

As shown on Figure 12-21, the highest concentrations of total PCBs as congeners in bass tissue occurred at locations 17 and 18, on the tip of the Bradford island, locations 3 and 16, which were also located adjacent to the island, and locations 2, 8, 11 and 13 in the Goose Island slough. Total PCBs as congeners concentrations in bass at these locations exceeded 10 times the SLV protective of individual birds, and PCB concentrations at locations 11 and 17 also exceeded 10 times the SLV protective of bird populations. Several other bass sample locations throughout the Forebay had PCB concentrations between 0.1 and 10 times the SLVs (Figure 12-21). The highest concentrations of the Avian TEQ in bass tissue (greater than 10 times the SLV) also occurred at locations 11 and 17, while concentrations in six samples fall between the SLV and 10 times the SLV, and concentrations in the remaining samples are between 0.1 times the SLV and the whole SLV.

The Avian TEQ was not identified as a CPEC in sediment (Tables N-55 and N-56). Total PCBs as congeners are a sediment CPEC and were detected in sediment from P4 at a concentration greater than 10 times the sediment SLV protective of individual birds and between 0.1 and 1 times the SLV protective of bird populations. Sediment total PCB concentrations were greater than 0.1 times the SLV protective of individual birds at several other locations. However, the affected area is unlikely to account for the PCB concentrations observed in the bass. Although the implications of these localized exceedances of the sediment SLV in terms of current site contribution to concentrations of PCBs in bass tissue are unknown, it is likely that the observed bass tissue levels reflect historical body burdens, influences from upstream sources, or a combination of the two.

Mercury was also measured in several bass samples at concentrations between 0.1 and 10 times the SLV (Figure 12-21). Although concentrations of mercury in Forebay bass were significantly higher than in the Reference Area (Table L-4), the concentration ranges in bass tissue were generally comparable between the Forebay (0.0710 – 0.512 mg/kg) and the Reference Area (0.0548 – 0.333 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediments were not significantly higher than those in the Reference Area.

Since mercury bass tissue concentrations are elevated throughout the Forebay, mercury bass tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful. Based on the ubiquitously elevated bass tissue concentrations for mercury, it is likely that other sources influenced the levels measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway) .

Risk management or monitoring is recommended for PCBs, and possibly mercury, in bass tissue to protect piscivorous birds that may be exposed through their diet. More confidence is placed in the R_{BACs} for PCBs measured as congeners, including totals as congeners and TEQs, for reasons previously stated. The low sediment R_{BAC} for PCB congeners in the Forebay and absence of mercury sediment concentrations above Reference Area sediment concentrations should be considered in risk management decisions regarding the best way to proceed with the ERA process.

Piscivorous Mammals

Tissue SLVs protective of piscivorous mammals were screened against the Forebay crayfish, sculpin, and smallmouth bass tissue data. Table N-82 summarizes the CPECs for piscivorous mammals identified in these randomly-collected tissues from the Forebay (Table N-57 and Table N-58). The CPECs shown with an asterisk in Table N-82 were also identified as CPECs in Forebay sediment (Tables N-59 and N-60). No population-level CPECs were identified for sediment.

As described in Section 12.5.4.1, EPCs for mercury exceeded the tissue SLVs. Seven other metals were detected in Forebay tissues and retained as CPECs due to the lack of tissue SLVs. However, the results of the population to population statistical comparisons demonstrated that none of these metals were present in the Forebay sediment at concentrations above Reference Area sediment concentrations (Table L-4). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels.

Although none of these metals are CPECs in sediment, the one present above the tissue SLVs (mercury) is recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

Figure 12-22 shows a sample by sample comparison of CPEC concentrations to SLVs for the protection of piscivorous mammals, both at the individual and population levels. Tissue and sediment concentrations are shown for mercury, total PCBs as congeners, and Mammalian TEQs.

Crayfish

The crayfish tissue R_{BACs} for total mercury at the individual and population levels were 0.198, and 0.119, respectively, and the R_{BACs} for methyl mercury were 0.274 and 0.165 (Table N-57 and Table N-58). Although total PCBs as congeners in crayfish tissue were not identified as a CPEC for mammals, three dioxin-like PCB congeners and the Mammalian TEQ were selected as CPECs (Tables N-57 and Table N-82). The crayfish tissue R_{BACs} for PCBs at the individual level ranged from 0.177 (PCB 156+157) to 2.01 (Mammalian TEQ), and no tissue CPECs were identified based on the population level evaluation for mammals.

As shown on Figure 12-22, the highest concentrations of Mammalian TEQs in crayfish tissue (between 1 and 10 times the SLV protective of individual mammals) occurred at P5-CF and P6-CF on the southeastern tip of the island. Mammalian TEQ concentrations in crayfish from P1-CF, P4-CF, and P7-CF were between 0.1 times the SLV and the whole SLV protective of individual mammals, and the remaining concentrations are below 0.1 times the SLV.

Total PCBs as congeners detected in sediment were below the SLVs (and sum $R_{BAC} < 1.0$) (Tables N-59 and N-60). The Mammalian TEQ and PCBs 105, 118, 126, and 156+157 were identified as CPECs in Forebay sediment (Tables N-59) based on exceedances of the sediment

SLV protective of individual mammals. Mammalian TEQ concentrations in sediment were below the SLVs protective of mammal populations (Table N-60). The Mammalian TEQ concentration in sediment at P4 is the only one in exceedance of the SLV protective of individual mammals (Figure 12-22), while Mammalian TEQ concentrations were between 0.1 times the SLV and the whole SLV at five locations.

Concentrations of mercury, including methyl mercury, in crayfish were all below the SLVs protective of mammals (individuals and the population). Mercury concentrations were between 0.1 times the SLVs and the SLVs protective of individual mammals and mammal populations in all but three crayfish samples collected throughout the Forebay. These three samples, which only had concentrations between 0.1 times the SLV and the SLV protective of individual mammals (below 0.1 times the SLV protective of populations), were P4-CF (former removal area), P20-CF (northwest shore of Goose Island), and P3-CF (southeast shore of Cascade Locks). Although concentrations of mercury in crayfish were significantly higher than in the Reference Area (Table L-4), the concentration ranges in crayfish tissue were generally comparable between the Forebay (0.0157 – 0.0315 mg/kg) and the Reference Area (0.0105 – 0.0246 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediment were no higher than in Reference Area sediment (Table L-4).

Since mercury crayfish tissue concentrations were only greater than 0.1 times the mammalian SLVs throughout the Forebay (R_{BACs} were low), mercury crayfish tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful. Based on the relatively uniform crayfish tissue levels for mercury in the River as a whole, it is likely that other sources influenced the concentrations measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway).

Given the lack of CPECs in crayfish tissue based on the comparison to SLVs protective of mammal populations, low R_{BACs} for the individual level evaluation, the absence of sensitive mammalian species at the site, the potential for adverse effects to mammals from consumption of crayfish tissue is low. No further investigation of crayfish for the protection of mammal populations is recommended.

Sculpin

The sculpin tissue R_{BAC} for mercury at the individual and population levels were 1.56, and 0.935, respectively (Table N-57 and Table N-58). The sculpin tissue R_{BACs} for PCBs at the individual level ranged from 0.183 (PCB 169) to 25 (PCB 118), and at the population level ranged from 0.148 (PCB 156+157) to 1.87 (total PCBs as congeners). The sculpin tissue R_{BACs} for the Mammalian TEQ at the individual and population levels were 25.2, and 0.913, respectively.

As shown on Figure 12-22, the highest concentrations of total PCBs as congeners in sculpin tissue (between 1 and 10 times the SLVs), occurred at SF-3, and SF-5 on the southeastern tip of the island. Total PCB concentrations in sculpin from SF-4 and SF-6 were between 0.1 and 1 times the SLVs. Mammalian TEQ concentrations in SF-3, SF-4, and SF-5 are greater than 10 times the tissue SLV, between the SLV and 10 times the SLV in nine samples, and concentrations in the remaining samples fall between 0.1 times the SLV and the whole SLV.

Total PCBs as congeners detected in sediment were below the SLVs (and sum $R_{BAC} < 1.0$) (Tables N-59 and N-60). The Mammalian TEQ and PCBs 105, 118, 126, and 156+157 were identified as CPECs in Forebay sediment (Tables N-59) based on exceedances of the sediment SLV protective of individual mammals. Mammalian TEQ concentrations in sediment were below the SLVs protective of mammal populations (Table N-60). The Mammalian TEQ concentration in sediment at P4 is the only one in exceedance of the SLV protective of individual mammals (Figure 12-22), while Mammalian TEQ concentrations were between 0.1 times the SLV and the whole SLV at five locations.

Mercury concentrations were between 0.1 and 10 times the SLV in several sculpin samples collected throughout the Forebay. Although concentrations of mercury in sculpin were significantly higher than in the Reference Area (Table L-4), the concentration ranges in sculpin tissue were generally comparable between the Forebay (0.037 – 0.308 mg/kg) and the Reference Area (0.0448 – 0.0141 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediment were no higher than in Reference Area sediment (Table L-4).

Since mercury sculpin tissue concentrations were elevated throughout the Forebay (R_{BACs} were relatively low), mercury sculpin tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful. Based on the ubiquitously elevated sculpin tissue levels for mercury in the River as a whole, it is likely that other sources influenced the concentrations measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway).

Risk management or monitoring is recommended for PCBs, and possibly mercury, in sculpin tissue to protect piscivorous mammals that may be exposed through their diet. However, the low sediment R_{BACs} for PCBs (including the Mammalian TEQs), and low concentrations of PCBs and mercury detected in the sediment samples relative to the tissue data, do not indicate a current source of PCBs and mercury in the Forebay. It is likely that the sculpin tissue levels reflect historical body burdens, influences from upstream sources, or a combination of the two.

Smallmouth Bass

The smallmouth bass tissue R_{BAC} for mercury at the individual and population levels were 2.64, and 1.59, respectively (Tables N-57 and N-58). The bass tissue R_{BACs} for PCBs at the individual level ranged from 0.295 (Aroclor 1242) to 331 (PCB 126), and at the population level ranged from 0.121 (PCB 114) to 12 (PCB 126). As stated previously, total PCBs as congeners was used to represent all PCB CPECs on the figures.

As shown on Figure 12-22, the highest concentrations of PCBs in bass tissue occurred at location 17, on northeastern tip of the island, and 11 in the Goose Island slough. Bass concentrations at these locations exceeded 10 times the SLVs protective of mammals at the individual and population levels. Several other locations near Bradford Island and Goose Island had PCB concentrations between 0.1 and 10 times the tissue SLVs.

Total PCBs as congeners detected in sediment were below the SLVs (and sum $R_{BAC} < 1.0$) (Tables N-59 and N-60). The Mammalian TEQ and PCBs 105, 118, 126, and 156+157 were identified as CPECs in Forebay sediment (Tables N-59) based on exceedances of the sediment SLV protective of individual mammals. Mammalian TEQ concentrations in sediment were below the SLVs protective of mammal populations (Table N-60). The Mammalian TEQ

concentration in sediment at P4 is the only one in exceedance of the SLV protective of individual mammals (Figure 12-22), while Mammalian TEQ concentrations were between 0.1 times the SLV and the whole SLV at five locations.

Mercury was also present at concentrations between 0.1 and 10 times the SLV in several bass samples. Although concentrations of mercury in Forebay bass were significantly higher than in the Reference Area (Table L-4), the concentration ranges in bass tissue were generally comparable between the Forebay (0.0710 – 0.512 mg/kg) and the Reference Area (0.0548 – 0.333 mg/kg). This is consistent with the fact that mercury concentrations in Forebay sediments were not significantly higher than those in the Reference Area sediment (Table L-4).

Since mercury bass tissue concentrations were elevated throughout the Forebay (R_{BACs} were relatively low), mercury bass tissue concentrations were similar between the Forebay and Reference Area, and concentrations of mercury in Forebay sediment were not elevated relative to the Reference Area, further risk assessment may not be helpful. Based on the ubiquitously elevated bass tissue concentrations for mercury, it is likely that other sources influenced the levels measured in the Forebay. It is recommended that future investigations evaluate potential site-related sources (e.g., Upland OU overland pathway).

Risk management or monitoring is recommended for mercury and PCBs in bass tissue to protect piscivorous mammals that may be exposed through their diet. More confidence is placed in the R_{BACs} for PCBs measured as congeners for reasons previously stated. The absence of sediment concentrations in exceedance of the bioaccumulation SLVs for PCBs and absence of mercury sediment concentrations above Reference Area sediment concentrations should be considered in risk management decisions regarding the best way to proceed with the ERA process.

12.5.4.3.2 Mouth of Eagle Creek

Benthic Invertebrates

Direct Toxicity Evaluation - PCBs (Aroclor 1248 and total Aroclors) were the only CPECs identified for the benthic community at the mouth of Eagle Creek based on the individual and multiple COI screening evaluations for sediment (Tables N-61 and N-62). Aroclor 1248 was assessed for its potential to elicit adverse effects in the benthic community.

Aroclor 1248 was detected at one of the two targeted sampling locations at Eagle Creek (Table I-9). The toxicity ratio for this sediment CPEC was 10.9. The toxicity ratio for total PCBs as Aroclors was 2.29. Aroclor 1248 was not detected in any other random or targeted locations in the Forebay (Table I-9) or in the Reference Area (Table I-11), including sediment and tissue samples. Aroclor 1254 was the primary PCB mixture detected in random sediment and tissue samples in the Forebay.

The elevated toxicity ratio for Aroclor 1248 indicates the potential for localized impacts to benthic invertebrates at the mouth of Eagle Creek. The absence of this CPEC in any other samples collected from the Forebay suggests that the Aroclor 1248 detection is not site-related. Given the potential for localized effects to the benthic community, however, Aroclor 1248 should be maintained as a CPEC for further investigation.

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which are based on a comparison of bioaccumulative COI concentrations in sediment to sediment SLVs protective of fish and shellfish.

Fish and Shellfish

Sediment SLVs protective of upper trophic level fish and shellfish that may be exposed through their diet were screened against the Eagle Creek sediment data (Table N-63). PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above the bioaccumulation SLVs. Aroclor 1248 was detected at one of the two targeted sampling locations at Eagle Creek (Table I-9). The toxicity ratios for Aroclor 1248 and total PCBs as Aroclors were 3.45 and 3.53, respectively. Aroclor 1248 was not detected in any other random or targeted locations in the Forebay or in the Reference Area, including sediment and tissue samples. Aroclor 1254 was the primary PCB mixture detected in random sediment and tissue samples in the Forebay.

The elevated toxicity ratios for Aroclor 1248 and total PCBs as Aroclors indicate the potential for localized impacts to fish and shellfish at the mouth of Eagle Creek. The absence of this CPEC in any other samples collected from the Forebay indicates that the Aroclor 1248 detection is not likely site-related. Given the influence of weathering and metabolic processes on the ability to identify PCBs measured as Aroclors in tissue, however, Aroclor 1248 is recommended for further investigation in Eagle Creek sediments as a possible contributor to PCB levels measured in fish tissue from the Forebay.

Carbazole was retained as a CPEC in sediment due to the lack of a bioaccumulation SLV. This sediment CPEC was detected in one of 19 Forebay random samples and was not detected in any of the clam (19 samples), crayfish (15 samples), or smallmouth bass (19 samples) random Forebay samples (Table L-4). Lack of evidence for bioaccumulation in site tissues is consistent with the low log K_{ow} for carbazole of 3.72 – which just barely falls within the optimal range for bioaccumulation of 3.5 to 6.5 (Suter 1993). Given the lack of carbazole in tissue collected from the Forebay, no further investigation is recommended.

Piscivorous Birds

Tissue SLVs protective of piscivorous birds were screened against the Eagle Creek data (Tables N-64 and N-65). Table N-64 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-65 shows the results of the population level assessment. PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above these bioaccumulative SLVs protective of individual birds. No CPECs were identified that could elicit adverse effects in bird populations.

Aroclor 1248 was detected at one of the two targeted sampling locations at Eagle Creek. The R_{BACs} for Aroclor 1248 and total PCBs as Aroclors based on the SLVs protective of individuals were 42.2 and 43.2, respectively. With the exception of these Eagle Creek samples, Aroclor 1248 was not detected in any random or targeted locations in the Forebay or the Reference Area, including sediment and tissue samples. Aroclor 1254 is the primary PCB mixture detected in random sediment and tissue samples.

The elevated R_{BACs} for Aroclor 1248 and total PCBs as Aroclors indicate the potential for localized impacts to individual protected threatened and endangered birds at the mouth of Eagle Creek. The absence of this CPEC in any other samples collected from the Forebay indicates that the Aroclor 1248 detection is not likely site-related. Given the influence of weathering and metabolic processes on the ability to identify PCBs measured as Aroclors in tissue, however, Aroclor 1248 is recommended for further investigation in Eagle Creek sediments as a possible contributor to PCB levels measured in fish tissue from the Forebay.

As stated above, carbazole was retained as a CPEC in sediment due to the lack of a bioaccumulation SLV. This sediment CPEC was detected in one of 19 Forebay random samples and was not detected in any of the clam (19 samples), crayfish (15 samples), or smallmouth bass (19 samples) random Forebay data (Table L-4). Lack of evidence for bioaccumulation in site tissues is consistent with the low log K_{ow} for carbazole of 3.72, which just barely falls within the optimal range for bioaccumulation of 3.5 to 6.5 (Suter 1993). Given the lack of carbazole in tissue collected from the Forebay, no further investigation is recommended.

Piscivorous Mammals

Tissue SLVs protective of piscivorous mammals were screened against the Eagle Creek sediment data (Tables N-66 and N-67). Table N-66 shows the results of the bioaccumulation screening to assess potential adverse effects at the individual level, and Table N-67 shows the results of the population level assessment. PCBs (Aroclor 1248 and total Aroclors) were detected in sediment at concentrations above these bioaccumulative SLVs protective of individual mammals. No CPECs were identified that could elicit adverse effects in mammal populations.

Aroclor 1248 was detected at one of the two targeted sampling locations at Eagle Creek. The R_{BACs} for Aroclor 1248 and total PCBs as Aroclors based on the SLVs protective of individuals were 1.73 and 1.77, respectively. With the exception of these Eagle Creek samples, Aroclor 1248 was not detected in any random or targeted locations in the Forebay or the Reference Area, including sediment and tissue samples. Aroclor 1254 is the primary PCB mixture detected in random sediment and tissue samples.

The elevated R_{BACs} for Aroclor 1248 and total PCBs as Aroclors indicate the potential for localized impacts to individual protected threatened and endangered mammals at the mouth of Eagle Creek. No impacts to mammal populations were demonstrated. No threatened or endangered mammal species are known to be present in the Forebay. Piscivorous mammals could access the sediment at the mouth of Eagle Creek during foraging due to the shallow water level and less challenging terrain compared to other areas of Forebay. However, the absence of Aroclor 1248 in any other samples collected from the Forebay indicates that the Aroclor 1248 detection is not likely site-related. Given the influence of weathering and metabolic processes on the ability to identify PCBs measured as Aroclors in tissue, however, Aroclor 1248 is recommended for further investigation in Eagle Creek sediments as a possible contributor to PCB levels measured in fish tissue from the Forebay. The low R_{BACs} for Aroclor 1248 in sediment of Eagle Creek should be considered, especially given the absence of threatened and endangered mammal species.

As stated above, carbazole was retained as a CPEC in sediment due to the lack of a bioaccumulation SLV. This sediment CPEC was detected in one of 19 Forebay random samples and was not detected in any of the clam (19 samples), crayfish (15 samples), or smallmouth bass (19 samples) random Forebay data (Table L-4). Lack of evidence for bioaccumulation in site tissues is consistent with the low log K_{ow} for carbazole of 3.72, which just barely falls within the optimal range for bioaccumulation of 3.5 to 6.5 (Suter 1993). Given the lack of carbazole in tissue collected from the Forebay, no further investigation is recommended.

12.5.4.3.3 Goose Island Slough

Benthic Invertebrates

Direct Toxicity Evaluation - Cadmium, thallium, zinc, and Aroclor 1254 were identified for the benthic invertebrate community in the Goose Island slough based on the individual and cumulative COI screening evaluations for sediment (Tables N-68 and N-69). The toxicity ratios for these CPECs range from 1.20 (zinc) to 1.74 (cadmium), and their concentrations in Goose Island sediment are fairly comparable to Reference Area sediment (Table L-7). Given the low toxicity ratios for these CPECs and lack of sensitive benthic invertebrate species in the Forebay, the potential for adverse effects to the benthic community through direct toxicity is low.

Bioaccumulation Evaluation - Refer to the findings of the evaluation for "Fish and Shellfish" below, which are based on a comparison of measured clam and crayfish concentrations from the site to tissue SLVs protective of fish and shellfish.

Fish and Shellfish

Tissue SLVs protective of upper trophic level fish and shellfish were screened against the targeted Goose Island clam, crayfish, and sculpin data (Table N-70). No CPECs were identified in these targeted tissue samples from Goose Island, with the exception of those for which no SLV is available: beryllium and p-cresol (4-methylphenol) (discussed below). PCBs were not identified as CPECs in clams, crayfish, or sculpin collected from Goose Island. As shown in Table N-51 and discussed above, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, and five of 12 dioxin-like congeners, and Fish TEQ), B2EHP, and butyl benzyl phthalate were identified as CPECs in randomly-collected smallmouth bass tissue samples from the Forebay. These bass tissue CPECs were evaluated in Goose Island sediments.

As described in Section 12.5.4.1, the EPC for mercury in bass tissue from the Forebay exceeded the tissue SLV. Four other metals were detected in Forebay bass tissue (aluminum, barium, beryllium, copper, and zinc) and beryllium was detected in clam tissue from Goose Island; all five metals were retained as CPECs due to the lack of tissue SLVs. However, the results of the comparison of maximum metals concentrations in Goose Island sediment to the Reference Area UPL concentrations in sediment demonstrated that only zinc was elevated in Goose Island sediment (Table L-7). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels, with the possible exception of zinc. The R_{BAC} for zinc in sediment based on the comparison to the Reference Area sediment UPL is low (1.40) (Table N-71). Since the maximum concentration of zinc in Goose Island sediment (148 mg/kg) is similar to the Reference Area sediment UPL (106 mg/kg) (Table L-7), , and zinc is an essential nutrient, the contribution of zinc in Goose Island sediment to Forebay bass tissue concentrations is questionable, especially since zinc was not elevated in the targeted clam and crayfish sample from Goose Island (these invertebrates are generally less mobile and more likely to accumulate localized CPECs than fish species).

None of the other metals are CPECs in sediment (Table N-71). However, because mercury is present in Forebay bass tissue above the tissue SLV protective of fish, mercury is recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

P-cresol was detected in one of the two sediment samples and in the single clam sample collected from Goose Island (Table L-6) and was retained as a CPEC due to the absence of SLVs. It was not detected in crayfish or smallmouth bass. P-cresol was detected in 11 of 18 sediment samples and 18 of 18 clam samples collected from the Reference Area (Table I-20a). Maximum

concentrations of p-cresol in the Reference Area sediment (210 µg/kg) and clams (110 µg/kg) (Table I-20a) are higher than concentrations detected in the Goose Island sediment (maximum of 8.5 µg/kg) and clams (maximum of 29 µg/kg) (Tables N-71 and N-70). Based on the low concentrations of p-cresol detected in Forebay sediment and clams in comparison to the Reference Area, and the low bioaccumulation potential for p-cresol (log K_{ow} = 1.94; Table J-7), which is consistent with the fact that P-cresol was not identified as a CPEC in sculpin, crayfish, or bass, lack of a quantitative risk-based screening for p-cresol is not expected to influence the findings of the ERA. No further investigation of p-cresol is recommended.

Of the organic CPECs listed above for randomly collected smallmouth bass tissue samples from the Forebay, PCBs (Aroclor 1254 and total Aroclors) were also identified as CPECs in Goose Island sediment (Table N-71) with sediment R_{BACs} of 0.45 and 0.57. These were approximately 3 times lower than the corresponding R_{BACs} for the randomly collected Forebay sediment samples (Table N-52). The low R_{BACs} for targeted Goose Island sediments (P110 and P111) and tissue (P110) samples do not suggest that sediment or food sources in the Goose Island slough contribute to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay (Figure 12-20).

Of the two phthalates identified as CPECs in randomly-collected smallmouth bass tissue samples from the Forebay (B2EHP and butyl benzyl phthalate), B2EHP was also detected in Goose Island sediment (Table 6-13b) and was retained as a CPEC due to the lack of a SLV that addresses the dietary pathway. B2EHP was not detected in the targeted samples of clams and crayfish from Goose Island (Table 6-13a). Butyl benzyl phthalate was not detected in any targeted samples collected from Goose Island (sediment, clams, or crayfish). Even for the bass tissue samples, the R_{BACs} for these two phthalates were low because neither are greater than the SLVs (they were retained as CPECs because their R_{BACs} are between 0.1 times the SLV and the whole SLV; Table N-51). Given the low concentration of butyl benzyl phthalate in Forebay bass tissue (below the SLV) and lack of detections in Goose Island media (sediment and tissue), no further investigation of butyl benzyl phthalate is recommended.

B2EHP was detected at concentrations between 0.1 and 1 times the SLV in two bass tissue samples collected from the Goose Island slough (Figure 12-20). The maximum detected concentration of this CPEC in Goose Island sediment (13 µg/kg; Table L-7) was more than 25 times lower than the maximum detected concentration in the random Forebay sediment samples (340 µg/kg; Table I-18a). The lower concentrations in Goose Island samples do not suggest a significant contribution on the elevated concentrations of B2EHP in smallmouth bass tissue from the Forebay. As discussed in Section 12.5.4.3.1 for the Random Forebay data, the low detection frequency (16%) for B2EHP in Forebay bass tissue (Table I-8a), low concentrations detected in bass (Table N-51), and absence of this CPEC in Goose Island tissues supports the position that phthalates are readily metabolized and weakly bioaccumulate (similar to the metabolic action noted in to PAHs). Given the low R_{BACs} for bass tissue and the minimal sediment B2EHP concentrations at Goose Island, no further evaluation of B2EHP is recommended to protect fish from exposure through the dietary pathway.

Piscivorous Birds

Tissue SLVs protective of individual piscivorous birds and bird populations were screened against the targeted Goose Island crayfish and sculpin data (Tables N-72 and N-73, respectively). No CPECs were identified in these targeted tissue samples from Goose Island, with the

exception of those for which no SLV is available: PAHs. PCBs were not identified as CPECs in crayfish or sculpin tissues collected from Goose Island.

As shown in Tables N-53 and N-54, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, seven dioxin-like congeners, and Avian TEQ), di-n-butyl phthalate, and PAHs were all identified as CPECs in randomly collected smallmouth bass tissue samples from the Forebay. PAHs were retained as CPECs due to the absence of tissue SLVs, and the implications of this uncertainty to the findings of the Screening Assessment are discussed in Appendix O.

As described in Section 12.5.4.1, the EPC for mercury in bass tissue from the Forebay exceeded the tissue SLV. Four other metals were detected in Forebay bass tissue and were retained as CPECs due to the lack of tissue SLVs. However, the results of the comparison of maximum metals concentrations in Goose Island sediment to the Reference Area UPL concentrations in sediment demonstrated that only zinc was elevated in Goose Island sediment (Table L-7). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels, with the possible exception of zinc. The R_{BAC} for zinc in sediment based on the comparison to the Reference Area sediment UPL is low (1.40). As the maximum concentration of zinc in Goose Island sediment (148 mg/kg) is similar to the Reference Area UPL (106 mg/kg) (Table L-7), and because zinc is an essential nutrient, the contribution of zinc in Goose Island sediment to Forebay bass tissue concentrations is questionable, especially since zinc was not elevated in the targeted clam and crayfish sample from Goose Island (these invertebrates are generally less mobile and more likely to accumulate localized CPECs than fish species).

None of the other metals are CPECs in sediment (Table N-74). However, because mercury is present in Forebay bass tissue above the tissue SLV protective of fish, mercury is recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

Of the smallmouth bass tissue organic CPECs listed above, PCBs (Aroclor 1254, total Aroclors, total congeners, one dioxin-like congener, and Avian TEQ) were also identified as CPECs in Goose Island sediment, with sediment R_{BACs} based on the protection of individual birds ranging from 0.107 (Avian TEQ) to 7.0 (total PCBs as Aroclors) (Table N-74). The R_{BACs} for the randomly collected Forebay sediment samples (Table N-55) are higher than the Goose Island sediment R_{BACs} for Aroclor 1254, total Aroclors, and total congeners (Table N-74), while the Goose Island sediment R_{BACs} for PCB 77 and the Avian TEQ are slightly higher than R_{BACs} for the randomly collected Forebay sediment samples. Sediment R_{BACs} for the Goose Island data based on the protection of bird populations are less than the SLV, but greater than 0.1 times the SLV for Aroclor 1254 and total Aroclors (Table N-75). Population level-based sediment R_{BACs} for the Goose Island data are less than 0.1 times the SLV for total congeners, PCB 77, and the Avian TEQ. The low R_{BACs} for PCBs (total congeners and Avian TEQ) in targeted Goose Island sediments and absence of CPECs in Goose Island tissue suggest that sediment and food sources in the Goose Island slough contribute minimally to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay (Figure 12-21).

Di-n-butyl phthalate was also detected in both Forebay bass and Goose Island sediment (Table 6-13b) (but not in clams and crayfish from Goose Island; Table 6-13a) and was retained as a CPEC.. Di-n-butyl phthalate was detected in one of 19 Forebay bass tissue samples and was not

detected in any other medium collected from the Forebay. It was not detected in Reference Area tissues, but was detected in Reference Area sediment at concentrations similar to those detected in the Goose Island sediment samples. The R_{BAC} for di-n-butyl phthalate in bass tissue from the Forebay was 0.24. Based on the absence of this compound from all but one Forebay tissue sample, the low concentration in this bass sample, and low concentrations in Goose Island sediment, no further investigation of di-n-butyl phthalate is recommended.

Piscivorous Mammals

Tissue SLVs protective of individual piscivorous mammals and mammal populations were screened against the targeted Goose Island crayfish and sculpin data (Tables N-76 and N-77, respectively). No CPECs were identified in these targeted tissue samples from Goose Island. As shown in Tables N-53 and N-54 and discussed above, aluminum, barium, copper, mercury, zinc, PCBs (Aroclors 1242 and 1254, total Aroclors, total PCB congeners, seven dioxin-like congeners, and Mammalian TEQ) are CPECs in randomly-collected smallmouth bass tissue samples from the Forebay. These bass tissue CPECs were evaluated in Goose Island sediments.

As described in Section 12.5.4.1, the EPC for mercury in bass tissue from the Forebay exceeded the tissue SLV. Four other metals were detected in Forebay bass tissue and were retained as CPECs due to the lack of tissue SLVs. However, the results of the comparison of maximum metals concentrations in Goose Island sediment to the Reference Area UPL concentrations in sediment demonstrated that only zinc was elevated in Goose Island sediment (Table L-7). Therefore, it is difficult to assess the contribution of the metal CPECs in site sediment to the Forebay tissue levels, with the possible exception of zinc. The R_{BAC} for zinc in sediment based on the comparison to the Reference Area sediment UPL is low (1.40). As the maximum concentration of zinc in Goose Island sediment (148 mg/kg) is similar to the Reference Area UPL (106 mg/kg) (Table L-7), and because zinc is an essential nutrient, the contribution of zinc in Goose Island sediment to Forebay bass tissue concentrations is questionable, especially since zinc was not elevated in the targeted clam and crayfish sample from Goose Island.

None of these metals are CPECs in sediment (Table N-78 and N-79). However, because mercury is present in Forebay bass tissue above the tissue SLV protective of fish, mercury is recommended for further investigation in tissue and sediment during future data collection efforts to better understand the potential site contribution.

Of the smallmouth bass tissue organic CPECs listed above, PCBs (Aroclor 1254 and total Aroclors) were also identified as CPECs in Goose Island sediment, with sediment R_{BACs} of 0.225 and 0.286 based on the protection of individual mammals (Table N-78). These are approximately 3 times lower than the corresponding R_{BACs} for the randomly collected Forebay sediment samples of 0.614 and 0.652 (Table N-59). Total PCBs as congeners, individual dioxin-like congeners, and the Mammalian TEQ were not identified as CPECs in sediment based on the individual and population level evaluations for mammals. Because PCBs (total congeners, individual dioxin-like congeners, and the Mammalian TEQ) were not identified as CPECs in targeted Goose Island sediments and tissue, it is likely that sediment and food sources in the Goose Island slough contribute minimally to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay (Figure 12-22).

12.5.5 Summary of Level II Screening Assessment for River OU

Tables N-80 through N-82 summarize the initial sediment and tissue CPECs for the benthic community, fish and shellfish (Table N-80), piscivorous birds (Table N-81), and piscivorous mammals (Table N-82) identified in the ERA screening tables for the River OU (both random and targeted Forebay datasets). As discussed in the Risk Interpretation (Section 12.5.4.3), some of these CPECs were eliminated from further evaluation based on low R_{BACs}, lack of detections in other tissue types, similarity between Forebay and Reference Area tissue concentrations, or concentrations in sediment below Reference Area sediment levels. Table 12-2 presents the CPECs for the Forebay that are recommended for risk management, which are cadmium, lead, mercury, and PCBs. Unlike the Upland OU, the River OU is not comprised of individual AOPCs. The Forebay was considered one exposure are, and the only differentiation between the Forebay data sets is a reflection of the specific sampling techniques employed (i.e., random or targeted). These four CPECs for the Forebay were identified through an evaluation of the random Forebay dataset. PCBs in sediment from Eagle Creek (targeted samples) are also recommended for risk management. Based on the evaluation of Goose Island sediment and tissue samples, no CPECs are recommended for risk management at these targeted locations (see further discussion below). All CPECs recommended for risk management based on the evaluation of clam, crayfish, sculpin, and smallmouth bass tissue are also recommended for risk management in sediment even though measured concentrations in Forebay sediment do not likely account for all of the elevated tissue levels.

Risk management or monitoring is recommended for cadmium, lead, mercury, and PCBs (Aroclors and 209 PCB congeners) in sediment and tissue from the Forebay to protect predatory fish and piscivorous wildlife that may be exposed through their diet. Aroclor 1248 was the only Aroclor detected at Eagle Creek and was not detected in any other random or targeted locations in the Forebay or in the Reference Area, including sediment and tissue samples. Aroclor 1254 is the primary PCB mixture detected in random Forebay sediment and tissue samples. The absence of Aroclor 1248 in any other samples collected from the Forebay indicates that the Aroclor 1248 detection in Eagle Creek sediment is not likely site-related. Given the influence of weathering and metabolic processes on the ability to identify PCBs measured as Aroclors in tissue, however, Aroclor 1248 is recommended for further investigation in Eagle Creek sediments as a possible contributor to PCB levels measured in fish tissue from the Forebay.

Based on the low R_{BACs} for targeted Goose Island sediments samples relative to the random Forebay R_{BACs} for PCBs, and the absence of elevated PCB concentrations in Goose Island tissues, PCB concentrations in the targeted Goose Island samples are likely to have contributed minimally to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay. Although the Aroclor data demonstrated elevated R_{BACs} in sediment, the available congener data, which is expected to provide a more accurate measure of total PCB concentrations, demonstrate acceptable R_{BAC} values. Although CPEC concentrations in media collected from the targeted Goose Island samples indicate acceptable risk levels, Goose Island will be maintained as part of the Forebay evaluation in the forthcoming FS in response to DEQ's request.

12.6 Recommendations

One of two options is recommended for the Upland AOPCs:

1. Evaluate targeted removal or remedial actions to decrease residual concentrations to acceptable risk levels or

2. Perform a site-specific Level III BERA to determine if risks are unacceptable.

If a Level III BERA is performed for soil in the Upland OU, the evaluation would be focused solely on the CPECs recommended for risk management for each AOPC (Table 12-1). Site-wide exposure to the combined AOPCs would be evaluated for wildlife receptors with larger home ranges (e.g., predatory birds).

The River OU is recommended for risk management, which may include further risk assessment or a feasibility study and long-term monitoring of cadmium, lead, mercury, and PCB concentrations (Table 12-2).

13.0 SUMMARY AND RECOMMENDATIONS

This RI report, including the screening level HHRA and ERA presented in Sections 11 and 12, documents the current conditions at the Bradford Island Upland and River OUs. The results are summarized separately for each of the Upland AOPCs and for the River OU, below. The HHRA and ERA also evaluated all four AOPCs combined for receptors that could regularly utilize all four AOPCs (i.e., on-site maintenance worker or terrestrial birds and mammals); however, no additional COPCs or CPECs were identified (when compared to those identified for the individual AOPCs).

13.1 Landfill AOPC

Physical and Chemical Characteristics

Historical use of the Landfill AOPC to manage, store, and dispose of waste materials has resulted in contamination of soil, groundwater, and seep water with chemicals associated with the wastes. The extent of the waste disposal area is well defined based on topography, review of historical aerial photographs, a geophysical survey, excavation of test pits, observation of wastes on the ground surface, and the analysis of soil, groundwater, seep ,and surface water samples. The type and magnitude of contamination is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the Landfill AOPC.

Soil throughout the Landfill AOPC is impacted by metals, PAHs, and other SVOCs. Impacts to soil from butyltins, herbicides, pesticides, PCBs, TPH, and VOCs are much more limited. Similarly, metals, TPHs, and VOCs were detected in groundwater throughout the Landfill AOPC, as well as at low concentrations in seep water sampled along the northern perimeter of the AOPC. Butyltins, herbicides, pesticides, PCBs, PAHs, and SVOCs had generally limited detections in groundwater. Butyltins, herbicides, pesticides, PCBs, and PAHs were not detected in seep water.

The majority of the ground surface at the Landfill AOPC is relatively flat, well vegetated, and shows minimal evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable and there is minimal potential for off-site migration of contaminated soil or buried debris. The north and east sides of the Landfill AOPC include steep slopes leading down to the Columbia River. Although the potential for mass wasting appears low, soil on these slopes has the potential to migrate to the Columbia River via mass wasting.

Human Health Risk Screening

Soils were evaluated for direct contact under occupational and soil-intrusive exposure scenarios and groundwater was evaluated for hypothetical use as a potable water supply source as well as discharge to the river. COPCs warranting additional consideration in soil at the Landfill AOPC included arsenic, cPAHs, and PCE. In addition, the degradation products of PCE as well as chromium and lead were also retained as COPCs based on DEQ's selection process. In groundwater, the COPCs warranting further consideration included arsenic, manganese, B2EHP, DNOP, TPH and several chlorinated VOCs. Several other VOCs and metals were also identified based on DEQ's selection process. The vast majority of non-carcinogenic compounds were not a concern.. Arsenic and cPAHs emerged as the carcinogenic COPCs contributing most to risk, along with PCE and TCE. Arsenic was retained in soil and groundwater at the Landfill AOPC for the Adult Outdoor worker and potable use exposure scenarios; cPAHs were retained in soils

for potential direct contact exposures for Adult Outdoor and Construction workers. Areas of the Landfill AOPC that pose the highest potential risk to human health include the Gully Test Pit and the Mercury Vapor Lamp Test Pit.

Finally, COPCs in Landfill soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for risk management.

Ecological Risk Screening

Only soil was identified as a medium concern for ecological receptors at the Landfill AOPC. The following CPECs warrant further consideration for all terrestrial receptors potentially exposed to soil (plants, soil invertebrates, birds, and mammals): antimony, chromium, copper, lead, mercury, nickel, and total HPAHs. The areas where the highest concentrations of these CPECs were observed include the mercury vapor-lamp test pit, lead hot-spot test pits #1 and #2, gully test pit, and pesticide/herbicide wash area. In addition, the bioaccumulative CPECs for which dietary-based SLVs are not available also warrant further consideration for birds and mammals (primarily pesticides and herbicides). Finally, CPECs in Landfill soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for risk management.

13.2 Sandblast Area AOPC

Physical and Chemical Characteristics

Historical and ongoing uses of the Sandblast Area AOPC include equipment storage and management, storage, and disposal of various hazardous substances and wastes. These uses have resulted in contamination of soil, groundwater, and soil gas with chemicals associated with the equipment and wastes. The extent of the contaminated area is defined based on topography, location of former and existing site features and structures, knowledge of former and current site uses, visual observation of wastes (i.e. sandblast grit) and equipment on the ground surface, and the analysis of soil, groundwater, and soil gas samples. The sandblast grit disposal area, the equipment laydown area, and an inferred VOC release at the current HMSA appear to be the primary sources of contamination.

Metals, pesticides, PCBs, PAHs, SVOCs, and VOCs were detected in soil samples from throughout the Sandblast Area AOPC. The type and magnitude of contamination is variable, consistent with the variable hazardous substance and waste management, storage, and disposal practices that occurred at the various subareas within the Sandblast Area AOPC. Metals, butyltins, pesticides, PAHs, TPHs, SVOCs, and VOCs were detected at low concentrations in groundwater, indicating that these contaminants are leaching from source area soils to groundwater. PCBs were not detected in groundwater. VOCs were detected in soil gas at locations corresponding to the footprint of the VOC plume originating at the current HMSA. This plume is in an area where there are currently no structures that could be occupied by site workers.

An area of potentially erodible soils, resulting from recent construction activities, was identified during a site visit in 2009. During the past year, this area has become revegetated and the soils are no longer considered erodible. Stormwater runoff from impervious surfaces (asphalt) drains to four catch basins that discharge to the Columbia River through two outfalls. It appears, however, that the majority of the runoff from asphalt immediately southeast of the former

sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. This runoff travels down the slope to the equipment laydown area and adjacent Landfill access road, and onto a vegetated area between the Landfill road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates before reaching the river.

Human Health Risk Screening

At the Sandblast Area, soils were evaluated for direct contact under occupational and soil-intrusive exposure scenarios and groundwater was evaluated for hypothetical use as a potable water supply as well as discharge to the river. In addition, soil gas was also evaluated for vapor intrusion into future enclosed structures. The COPCs identified in soil were primarily arsenic, chromium, lead, PCE, and cPAHs. In addition, the degradation products of PCE were also identified as COPCs based on DEQ's selection process. The COPCs in groundwater were arsenic, cPAHs, PCE, TCE and vinyl chloride. Vanadium and some TPH fractions were also identified as COPCs based on DEQ's selection process. The COPCs in soil gas were primarily PCE, TCE and their degradation compounds. Lead in soil may be a minor contributor to non-cancer hazards at the Sandblast Area AOPC. Arsenic, chlorinated VOCs, and cPAHs were the primary carcinogenic COPCs. VOCs in soil and soil gas are a concern in the vicinity of SB-10 and SB-12.

Ecological Risk Screening

Only soil was identified as a medium concern for ecological receptors at the Sandblast Area AOPC. The following CPECs warrant further consideration for all terrestrial receptors potentially exposed to soil: antimony, cadmium, chromium, lead, mercury, nickel, B2EHP, and total HPAHs. Areas with soil concentrations exceeding ecological screening values occurred throughout the AOPC, including the spent sandblast grit disposal area, around CB-1, the equipment laydown area, south of the current HMSA, and within the area where soils were identified as erodible in 2009. In addition, the bioaccumulative CPECs for which dietary-based SLVs are not available also warrant further consideration for birds and mammals (primarily pesticides and herbicides). Finally, CPECs in Sandblast Area soils identified through the evaluation of potential transport to the River OU via erosion are also recommended for risk management.

13.3 Pistol Range AOPC

Physical and Chemical Characteristics

Historical use of the Pistol Range AOPC as a firing range has resulted in the contamination of surface soil with lead and zinc. It is unlikely that significant concentrations of lead or zinc are leaching to groundwater. The Pistol Range AOPC may also be a historical source of zinc to the adjacent lagoon sediment. Currently, the area is well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition.

Human Health Risk Screening

At the Pistol Range, soils were evaluated for direct contact under occupational exposure scenarios. Groundwater was evaluated as a hypothetical potable water supply source and for discharge to the river. Lagoon sediments were also evaluated for off-shore exposures. Current and likely exposure pathways for offsite human receptors to COIs from the Pistol Range are

insignificant. No COPCs warranting further consideration were identified in soil, groundwater or sediments at this AOPC. The Pistol Range AOPC is not considered to pose a threat to human health and is not recommended for any further human health risk evaluation

Ecological Risk Screening

Only lead in soil was identified as a CPEC and medium of concern for the Pistol Range AOPC. Areas with soil lead concentrations exceeding ecological screening values occurred behind the backstop and at the eastern corner of the former firing shed.

13.4 Bulb Slope AOPC

Physical and Chemical Characteristics

Placement of debris at the Bulb Slope AOPC has resulted in the contamination of soil with lead, mercury, and PCBs. The lateral extent of contamination is well constrained by the visible presence of debris in the soil and the underlying siltstone bedrock defines the vertical extent of contamination. Groundwater is not present. Soils may potentially be transported to the adjacent Columbia River by mass wasting.

Human Health Risk Screening

Due to the lack of COPCs for the exposure pathways identified in the CEM, the Bulb Slope AOPC is not considered to pose a threat to human health and no further consideration of human health is warranted.

Ecological Risk Screening

Lead and mercury in soil were identified as CPECs for the Bulb Slope AOPC. In addition, CPECs in Bulb Slope soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for risk management.

13.5 River OU

Physical and Chemical Characteristics

Historical disposal of electrical debris into the Columbia River along the north side of Bradford Island has resulted in the contamination of the surrounding sediment with PCBs and potentially other compounds. The electrical equipment and debris were removed in 2000 and 2002 and the majority of the associated PCB-contaminated sediment was removed in 2007. Residual contaminated sediment, as well as historically contaminated biota (e.g., fish and shellfish) may currently be sources of contamination.

Historical sampling, supported by hydrologic modeling, demonstrated that sediment from the Forebay is not transported upstream beyond Goose Island. Sediment samples collected downstream of the dam demonstrated that contaminated sediment is not being transported beyond the Forebay. Therefore, the boundaries of the River OU include the Bonneville Dam and Spillway, the two powerhouses, the riverbanks of the Columbia River, and the northern end of Goose Island.

The nature of the contamination in the Forebay has been characterized by both random and targeted sampling of surface water, sediment, and various tissues. The targeted sampling included sediments at the mouth of Eagle Creek, as well as sediments and tissue from Goose

Island Slough. To characterize conditions upstream of the site, random sampling of surface water, sediment, and tissues was also conducted in the River Reference Area. This allows the distinction between potential risks that may be associated with the Forebay from potential risks that are due to other sources.

Population-to-population statistical comparisons showed that for all metals, concentrations observed in the 19 random Forebay sediment samples were not significantly higher than the concentrations observed in the 18 random Reference Area samples. Statistical comparisons also showed that concentrations of organic compounds were not significantly higher in Forebay sediment than in the Reference Area sediment, with the exception of RRO and PCBs.

Tissue samples collected in the Forebay were found to have elevated concentrations of some metals, B2EHP, and various HPAHs. However, no clear spatial pattern was observed for any of these COIs. And, since the COIs were not found at concentrations of concern in Forebay sediments, the source(s) of these COIs are unclear.

PCBs have impacted biota in the Forebay. The clams, crayfish, and sculpin with the highest total PCB concentrations were all located along the north shore of Bradford Island. The spatial distribution of total PCB concentrations in bass was much more variable. Some of the bass with the highest concentrations were caught adjacent to bass with the lowest concentrations. This lack of a spatial pattern is consistent with bass migrating into the Goose Island Slough to spawn, bringing with them a wide range of PCB body burdens picked up from various locations in the Forebay. Targeted sampling of sediment, clams, sculpin, and crayfish from the Goose Island Slough did not find any difference between the slough and the remainder of the Forebay (excluding the north shore and tip of Bradford Island.) It is also important to remember that the Forebay bass were collected in 2006, before the 2007 sediment removal. Some of the older bass were estimated to have been up to 10 years old in 2006, meaning that they were exposed to conditions before the electrical debris and contaminated sediments were removed.

Human Health Risk Screening

In the River OU, sediments, surface water, crayfish tissue and smallmouth bass tissue were evaluated for exposure via the shellfish and fish consumption pathway for subsistence and recreational fishers. Surface water was also evaluated for use as a potable water supply. Sediments in the area of Eagle Creek were evaluated for direct contact exposures by waders. Sediments and tissue from Goose Island Slough were also included in the evaluation.

The COPCs that are recommended for risk management in the River OU include the following:

- Sediment – PCBs, mercury
- Surface Water – Arsenic, PCBs
- Crayfish tissue – Arsenic, PCBs
- Smallmouth Bass tissue – Mercury, cPAHs, PCBs
- Eagle Creek Sediments – PCBs, cPAHs, TPH
- Goose Island Sediments – PCBs
- Goose Island Crayfish – PCBs

An expanded list of COPCs that were identified through DEQ's selection process but are not expected to contribute significantly to risk is provided in Table 11-3.

In general, PCBs contributed the most to health risk for sediment (bioaccumulation) and crayfish and smallmouth bass tissue consumption for both subsistence and recreational fish consumers. Arsenic was also consistently selected as a COPC and to a lesser extent, cPAHs and mercury (only in bass tissue and sediments). Aroclor 1248 was the primary COPC in Eagle Creek sediments. Goose Island is recommended for management at the request of DEQ although its contribution to human health risk is likely to be low. The observed concentrations in tissues are likely the result of historical body burden and may not represent current exposure conditions.

Ecological Risk Screening

The CPECs in sediment and tissue of the Forebay that are recommended for risk management to protect ecological receptors include the following:

- benthic community – PCBs in sediment
- fish and shellfish – cadmium, lead, mercury, and PCBs in sediment and tissue
- aquatic-dependent birds and mammals – mercury and PCBs in sediment and tissue.

These four CPECs for the Forebay were identified through an evaluation of the random and targeted Forebay datasets. All CPECs recommended for risk management based on the evaluation of clam, crayfish, sculpin, and smallmouth bass tissue are also recommended for risk management in sediment even though measured concentrations in Forebay sediment do not likely account for all of the elevated tissue levels. For example, the results of the population to population statistical background comparisons demonstrated that metals concentrations in Forebay sediment are below Reference Area sediment concentrations. In addition, the observed concentrations of PCBs in fish tissue (especially smallmouth bass) are likely the result of historical body burden and may not represent current exposure conditions.

Given the low risk levels estimated for targeted Goose Island sediments samples relative to the risk levels estimated for the random Forebay for PCBs, and the absence of elevated PCB concentrations in Goose Island tissues, PCB concentrations in the targeted Goose Island samples are likely to have contributed minimally to the elevated concentrations of PCBs measured in smallmouth bass tissue from the Forebay. Although the Aroclor data for Goose Island demonstrated elevated risk estimates for sediment, the available congener data, which are expected to provide a more accurate measure of total PCB concentrations, demonstrate acceptable risk levels. Although CPEC concentrations in media collected from the targeted Goose Island samples indicate acceptable risk levels, Goose Island will be maintained as part of the Forebay evaluation in the forthcoming FS in response to DEQ's request.

PCBs were identified as a concern in sediment at three locations within the Forebay: stations P04 on the north shore of Bradford Island, P09 on the south side of the island (for birds only), and P43 at the mouth of Eagle Creek. Elevated concentrations of PCBs in sculpin and bass tissue were more widespread, although the observed concentrations are likely the result of historical body burden. PCB concentrations in crayfish tissue were notably lower than the concentrations detected in the other tissues (clams, sculpin, and bass). PCBs are the only CPEC in crayfish that were recommended for further consideration, which is based on slightly elevated risk levels for aquatic-dependent birds. This recommendation stems from the known presence of protected bird species in the vicinity of Bradford Island. However, crayfish are not a driver species for birds due to the much higher concentrations detected in sculpin and bass tissue.

13.6 Limitations of Screening Level Risk Assessments

The HHRA problem formulation (Chapter 11) relies on conservative assumptions regarding highly-uncertain parameters, such as duration of contact with soils and sediment, fish/shellfish consumption rates, quantity of untreated groundwater or surface water consumed, etc. If a BHHRA is performed for one or more OUs or AOPCs, site specific factors can be considered. Examples include:

1. Actual site use and reasonably-likely duration of work activities at each Upland AOPC.
2. Actual drinking water sources in use at the site.
3. Actual human consumption rates for Forebay bass for both subsistence and recreational fishers.
4. Actual human consumption rates for Forebay crayfish for both subsistence and recreational fishers, if such consumption even occurs.
5. Use of whole-body crayfish and fish tissue data instead of edible portions only.
6. Actual occurrence of different forms of compounds such as arsenic, chromium, mercury, PAHs and phthalates which have different levels of bioavailability and toxicity based on chemical species and exposure media, different degrees of accumulation in edible tissue, and variations in, metabolic pathways that affect their persistence.

Similarly, the Level II ERA (Chapter 12) also used conservative SLVs which generally assume worst-case exposure scenarios. If a Level III BERA is performed at one or more OUs or AOPCs to better understand the potential for adverse effects to ecological receptors, the following site-specific factors would be considered:

Plants

The studies upon which terrestrial plant SLVs were derived typically use crops as the test species, and sensitivity levels of undomesticated plant species are likely to be different than crop species. Effects to the plant community are likely to be overestimated due to the assumption that these organisms are exposed to the maximum concentration of each CPEC throughout their life span. No sensitive plant species are known to be present at the Upland OU.

Soil Invertebrates

Potential effects to the soil invertebrate community are likely to be overestimated by the SLVs due to the assumption that these organisms are exposed to the maximum concentration of each CPEC throughout their life span. In addition, studies used to develop SLVs for invertebrates commonly use earthworms as the test organism and, hence, earthworms are used to represent the entire soil invertebrate community. No sensitive invertebrate species are known to be present at the Upland OU.

Birds

1. The approach for the Level II Screening Assessment focused on protection of birds at the individual level to account for the bald eagle, and possible transient juvenile spotted owls, but these special-status species are not likely to forage at the AOPCs. The disturbed nature of some of the Upland AOPCs, (e.g., Landfill and Sandblast Area) which have

been graded and continuously subjected to vegetation control activities, precludes high quality habitat and species diversity. Furthermore, no state- or federally listed threatened and endangered terrestrial species are known to occur on the island, with the exception of the bald eagle (which is evaluated for the River OU). For these reasons, protection of terrestrial bird species at the population-level would be emphasized in the BERA for the Upland OU.

2. The site-specific Reference UPLs were greater than the risk-based soil SLVs (EcoSSL for lead and Avian PRG for mercury) and, therefore, the SLVs were replaced by the UPLs in the screening evaluation. In addition to evaluating specific bird target species and using literature-based BAFs to estimate dose, the contribution of background levels of metals would also be considered to better understand site-related dose contribution.
3. The size of the each AOPC or OU relative to the size of a birds' home range would be factored into the daily dose estimation.

Mammals

1. Site-specific mammal target species would be evaluated.
2. Literature-based BAFs would be used to estimate dose.
3. The contribution of background levels of metals would also be considered to better understand site-related dose contribution.
4. The size of each OU or AOPC relative to the size of a mammal's home range would be factored into the daily dose estimation.

13.7 Recommendations

Landfill AOPC

Based on the screening level risk assessments at the Landfill AOPC, implementation of one of two options is recommended:

1. Perform a FS to identify targeted soil removal or other remedial actions which will decrease residual concentrations to acceptable risk levels or
2. Perform a site-specific BHHRA and a Level III BERA to determine if risks to human and ecological receptors are unacceptable.

Sandblast Area AOPC

Further site-specific evaluation of human exposures to lead in soil using the size fraction-specific data is not necessary. However, based on the screening level risk assessment for soil gas at the Sandblast Area AOPC, an evaluation of the feasibility of a using a vapor extraction system or other remedial techniques to achieve acceptable soil gas VOC concentrations is recommended.

In addition, implementation of one of two options is recommended for addressing soil contamination:

1. Perform a FS to identify targeted soil removal or other remedial actions which will decrease residual concentrations to acceptable risk levels or

2. Perform a site-specific BHHRA and a Level III BERA to determine if risks to human and ecological receptors are unacceptable.

Pistol Range AOPC

No additional evaluation of this AOPC is warranted for potential human health risk. However, further action addressing the potential for risk to ecological receptors from exposure to lead is recommended - either in the form of a Level III BERA or remediation of the soils with elevated CPEC concentrations (primarily behind the backstop). If a Level III BERA is performed for lead in soil to better understand the potential for adverse effects to terrestrial plants, soil invertebrates, birds, and mammals, site-specific factors would be considered (i.e., absence of special-status species, AOPC size [0.26 acres], contribution of background levels of lead, *etc*.).

Bulb Slope AOPC

No additional evaluation of this AOPC is warranted for potential human health risk. However, further action addressing the potential for risk to ecological receptors from exposure to lead and mercury is recommended - either in the form of a Level III BERA or remediation of the soils with elevated CPEC concentrations. If a Level III BERA is performed for lead and mercury in soil to better understand the potential for adverse effects to terrestrial plants, soil invertebrates, birds, and mammals, site-specific factors would be considered (i.e., absence of special-status species, AOPC size [0.05 acres], contribution of background levels of lead and mercury, *etc*.).

River OU

Neither a Level III BERA nor a BHHRA is recommended for the River OU. Instead, progression to a FS is recommended. PCBs (through the consumption pathway) were identified as the primary risk drivers for both humans and wildlife, and secondarily cadmium, lead, and mercury for fish and wildlife (through the consumption pathway). All COPCs recommended for risk management based on the evaluation of site-specific tissue data are also recommended for risk management in sediment even though measured concentrations in Forebay sediment do not likely account for all of the elevated tissue levels. For example, the results of the population to population statistical background comparisons demonstrated that concentrations of cadmium, lead, and mercury in Forebay sediment are below Reference Area sediment concentrations.

The PCB concentrations remaining in Forebay sediment (after the 2002 and 2007 removal actions) are inconsistent with PCB concentrations measured in Forebay tissue (most notably in smallmouth bass). This is attributed to the fact that the bass were collected in 2006, prior to the sediment removal action, and are therefore not representative of current Forebay conditions. Similarly, the lifespan of crayfish and sculpin is also long enough that the concentrations measured in these samples probably also incorporate exposure to pre-sediment removal conditions. Monitoring of PCB concentrations in Forebay tissue may be recommended to confirm that tissue concentrations are decreasing with time and that residual sediment concentrations are at acceptable levels.

13.8 Post-RI Activity

As part of the pre-FS work for the River OU, additional bass, clam, and sediment samples were collected. In order to meet project goals of nineteen bass samples from the Forebay and Reference Area from a wide range of ages, twenty-three bass samples were collected from the Reference Area in August 2011 and twenty-three bass samples were collected from the Forebay

in September 2011. In the Forebay, bass were collected north of Bradford Island, north of Goose Island, and south of Cascade Island. Of the twenty-three samples collected from each area, four samples from the Reference Area and three samples from the Forebay were not analyzed because they comprised very young bass and were not needed to meet the project goals.

The sediment and clam samples were collected from seven locations along the north-shore of Bradford Island in October 2011. The co-located sediment and clam samples were collected in the areas suggested by DEQ as most likely to be influenced by Upland sources. Sediment samples were successfully collected at all seven proposed sample locations. While clams were located and collected at all seven proposed sample locations, only six of the locations yielded enough clam tissue for the planned analysis.

Sediment and tissue samples were analyzed for PCBs (Aroclors and 209 congeners), metals, PAHs, pesticides, butyltins, and SVOCs. This data will be presented in a subsequent document and will be used to verify the COPCs identified in the RI/RA for the River OU, as well as the COPCs originating from erosion or mass wasting evaluation of soils from the Upland OU. If the results indicate a potential source of contamination was overlooked, the list of sediment and tissue COPCs may be modified to reflect the new information. A more thorough evaluation of the potential for erosion and mass wasting of Upland soils will be conducted during the FS phase to support conclusions made regarding the likelihood and magnitude of the overland transport pathway.

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